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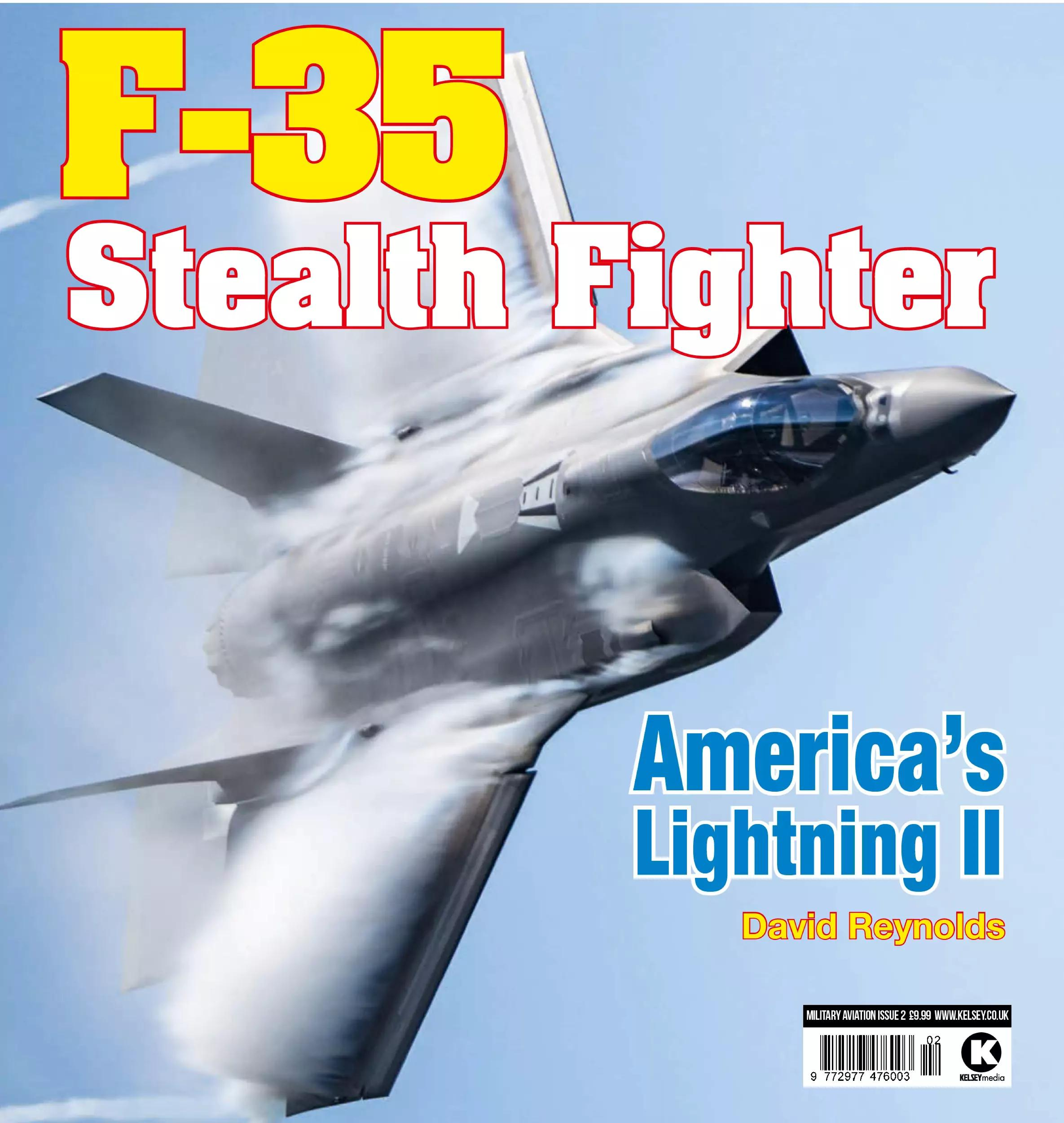

F-35
Stealth Fighter

America's Lightning II

David Reynolds

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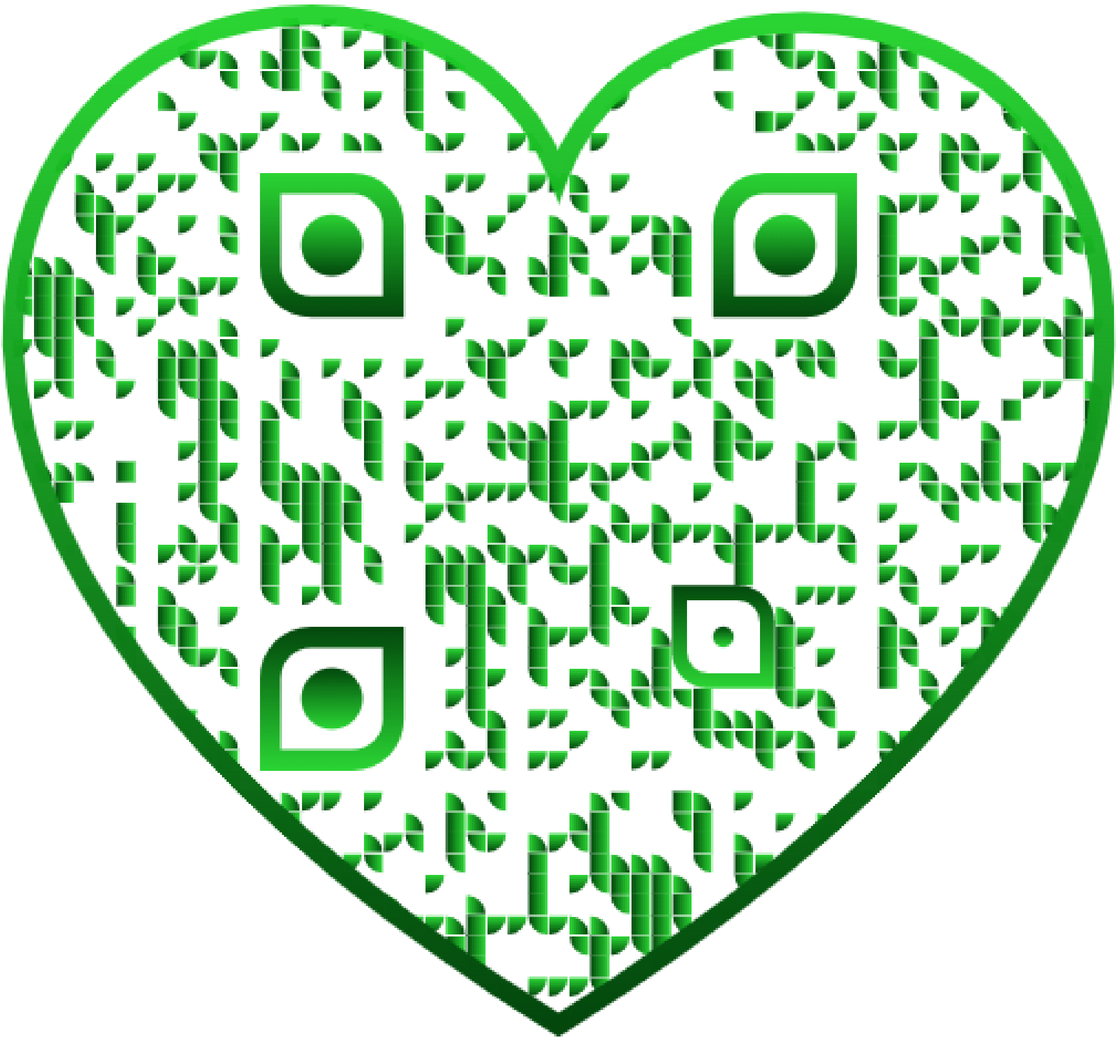

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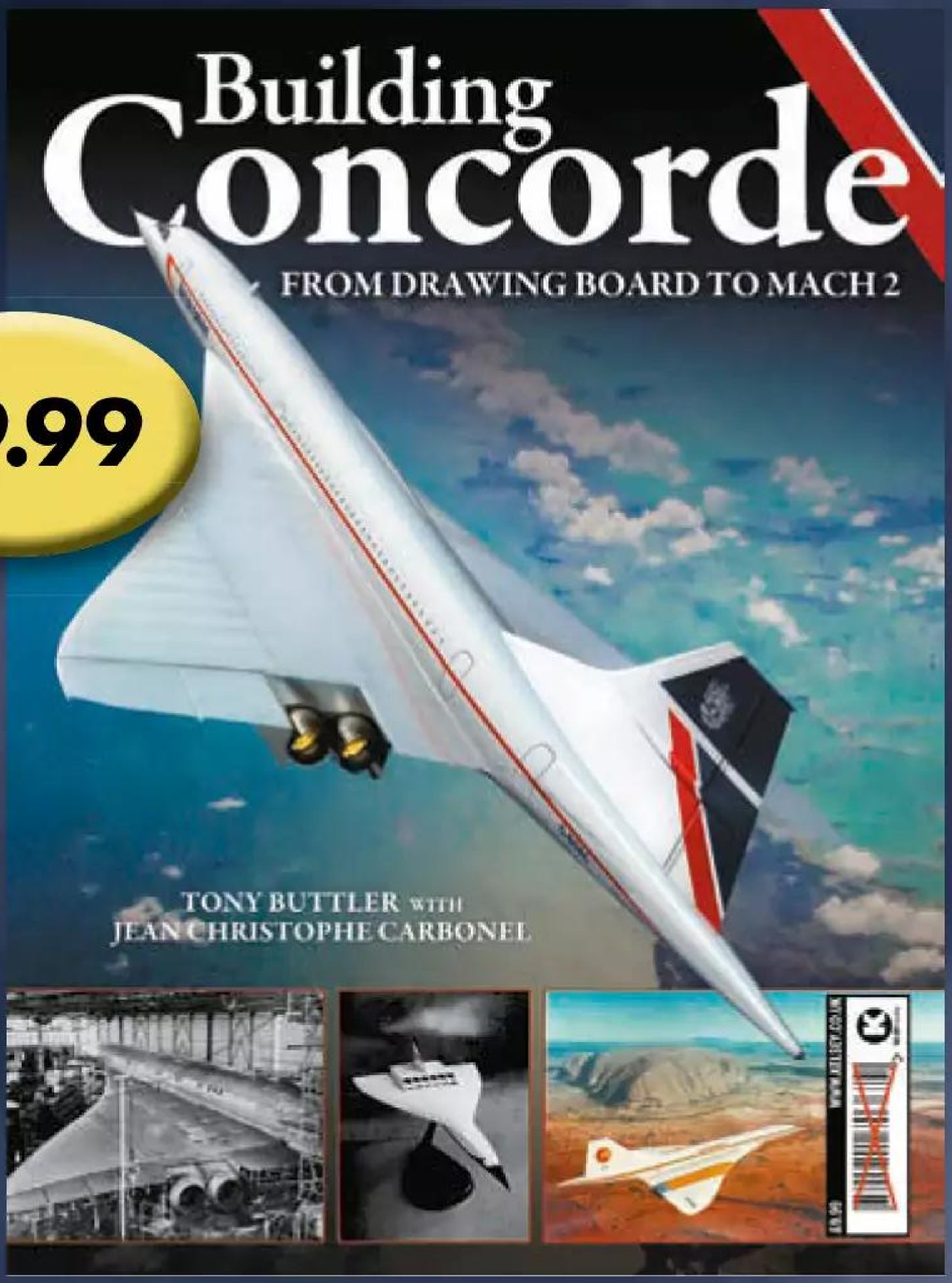

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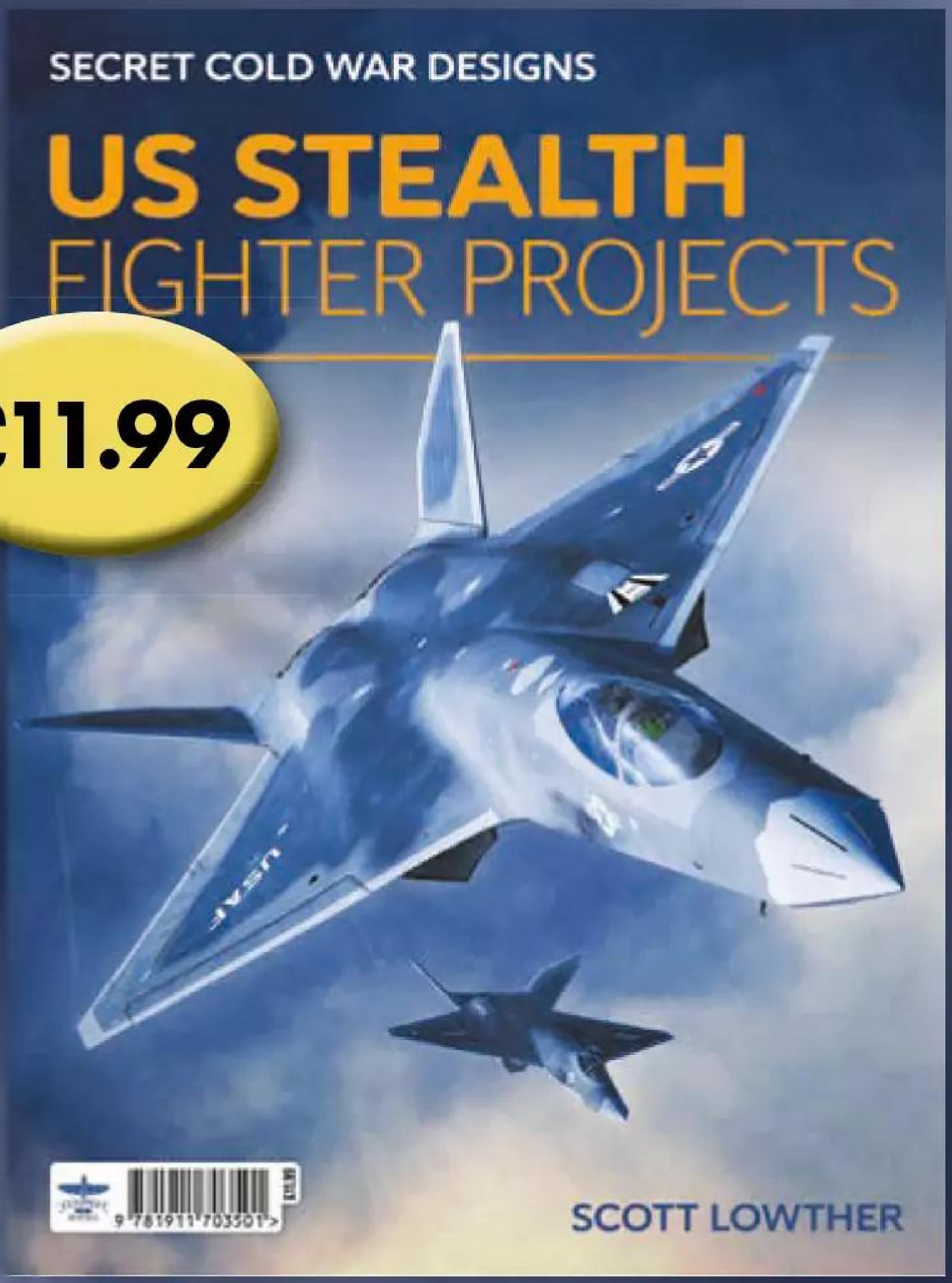

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F-35 - LIGHTNING II

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Design: Druck Media
Cover Design: Arun Verma

Kelsey Publishing Ltd.
Registered No. 02387149.

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Introduction

The F-35 Lightning II is a fifth-generation, single-seat, single-engine, supersonic stealth strike fighter, designed by Lockheed Martin for the US military and in service with European and Asian nations. It delivers air superiority in the land and maritime domains, operating from aircraft carriers, assault ships and deployed bases. It has been designed to replace aging aircraft including the US Air Force's F-16 Fighting Falcon, the A-10 Thunderbolt, the US Navy's F/A-18s, the US Marine Corps AV-8B Harriers and F/A-18s as well as the UK's Harrier GR.7s and Sea Harriers. It is a multirole combat aircraft with advanced sensors that enable intelligence, surveillance, reconnaissance, and electronic warfare gathering at a faster pace than any previous system. Its sensors include the Distributed Aperture System (DAS) which system provides pilots with situational awareness in a sphere around the aircraft for enhanced missile warning, aircraft warning, and day/night pilot vision.

Additionally, the aircraft is equipped with the Electro-Optical Targeting System (EOTS). This internally mounted system provides extended range detection and precision targeting against ground targets, as well as long range detection of air-to-air threats. The pilot's helmet-mounted display system is the most advanced of its kind and provides all the information an F-35 pilot needs to complete the mission, all of which is displayed on the helmet's visor. The F-35 contains state-of-the-art tactical data links that provide the secure sharing of data with other airborne, surface and ground-based platforms involved or supporting assigned missions.

Sold across the globe to NATO nations, including the United Kingdom, Italy, the Netherlands, Canada, Denmark, Norway and Australia as well as South Korea, Japan and Singapore. Lockheed Martin also produces a unique model for Israel, called the Adir. The F-35 is produced in three variants with the F-35A used by the United States Air Force for conventional take-off and landing, the F-35B by the US Marines for short take-off and vertical landing (STOVL), while the F-35C is fielded by the US Navy and operated from the fleet's aircraft carriers. The F-35 is well on its way to becoming the standard front-line fighter of the free world, with recent combat in the Middle East dispelling any lingering doubts about its formidable capabilities.

David Reynolds

1
CHAPTER

F-35 – America's Stealth Strike Fighter

The F-35 is America's new advanced strike fighter, designed to ensure that Washington's armed forces remain the most well-equipped in the world. The project to build the aircraft began more than three decades ago and was initiated to find a replacement for the Harrier, the F-16 Fighting Falcon, the F/A-18 Hornet and the A-10 Thunderbolt II. The aircraft is in a league of its own, with superior technology that has allowed engineers to harness the power of sensors and cutting-edge computer chips. The result is a fifth-generation strike fighter that allows pilots to share data links with other operational assets on the ground and at sea.

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An F-35A with the 33rd Fighter Wing 'Nomads' circles before landing at Eglin AFB. The first production F-35 was delivered to Eglin on July 14, 2011. **Picture USAF**

Groundbreaking design

There were those who believed, during its early development, that the F-35 was a monumentally expensive mistake – yet the stealth strike fighter has confounded the critics and the doubters to emerge as arguably the most effective multirole combat aircraft in service today. What it lacks in raw speed and manoeuvrability, it more than makes up for in its unparalleled ability to evade detection, its surprising range and its advanced surveillance and communications systems. Its development began in the early 1990s, when McDonnell Douglas, Northrop Grumman, Lockheed and Boeing were invited to make submissions for the new aircraft. Lockheed (which later merged with Martin Marietta to form Lockheed Martin) and Boeing were selected and invited to submit design proposals to build the aircraft, which included the construction of two demonstrator types, Lockheed's X-35 and Boeing's XB-32. Both delivered groundbreaking designs.

The road to the F-35 programme had been long and challenging. The collapse of the Soviet Union in 1991 resulted in the inevitable review of defence spending and aspirations as a peace dividend. At the time Washington was financing the development of the then-new Advanced Tactical Fighter, the F-22 Raptor, and its cost kept growing. In addition, the innovative Joint Services Vertical Take-off/Landing (listed as JVX) programme to develop and commission the revolutionary tilt-rotor helicopter, the V-22 Osprey, was also facing increased project costs and technical challenges. The US Army, concerned at the slow progress, had dropped out of the venture, stating a need to focus its budget on more immediate aviation requirements. The US Navy (USN), US Air Force (USAF) and US Marine Corps (USMC) now faced soaring costs amid increased fears that the V-22 overspend would impact other defence aviation spending. In 1988, the then-Defense Secretary Dick Cheney claimed the project was costing too much and tried to defund the V-22, but this proposal was overruled by Congress.

Despite all these concerns about defence spending, new projects continued to receive support, though some in Congress suggested that they should be merged. In the early 1990s, the Joint Advanced Strike Technology (JAST) project emerged, following the merger of the USAF's Multi-Role Fighter (MRF) and the USN's Advanced Attack/Fighter (A/F-X) programmes. The remit for those working on JAST was not to focus on the development of a specific new advanced strike aircraft, but rather to identify the requirements for one.

At the same time, work was underway to find a replacement for the successful Harrier jump-jet; the RAF's GR.1 Harrier and the Royal Navy's Sea Harrier had been successfully deployed by the British to the Falklands in 1982 after Argentine forces invaded the islands. The first example of the substantially different American-made variant, the McDonnell Douglas AV-8B, had been delivered to Marine Attack Training Squadron 203 (VMAT-203) at Marine Corps Air Station Cherry Point on December 12, 1983 and officially handed over one month later. It was understood, however, that the Harrier would eventually need a next-generation replacement.

A NASA-led joint US-UK programme known as Advanced Short Take-Off/Vertical Landing (ASTOVL) was subsequently launched in the late 1980s, which aimed to look at different propulsion systems for aircraft with those capabilities. This then evolved and developed, with the involvement of the US Navy and Defense Advanced Research Projects Agency (DARPA), into the Short Take-off and Vertical Landing (STOVL) Strike Fighter programme (SSF) – before then changing again to become the Common Affordable

The A-10 Thunderbolt II close-support platform is one of the aircraft that the F-35 was intended to replace. **Picture USAF**

The F-35 picks up where the F-117 Nighthawk stealth bomber left off. **Picture US DoD**

The F-16 Fighting Falcon is also listed for replacement by the F-35. **Picture US DoD**.

The X-35 Joint Strike Fighter demonstrator pictured during flight tests over Edwards Air Force Base, California. **Picture USAF**

Lightweight Fighter (CALF) programme.

By 1994 all of these programmes had been merged into the earlier JAST project. This programme now involved the USAF, the USMC, the US Navy and the UK's armed forces. As JAST moved forward, its purpose was expanded with the requirement to develop an aircraft with stealth capabilities that would replace not only the Harrier in US and UK service but also the F-16, A-10 and F/A-18.

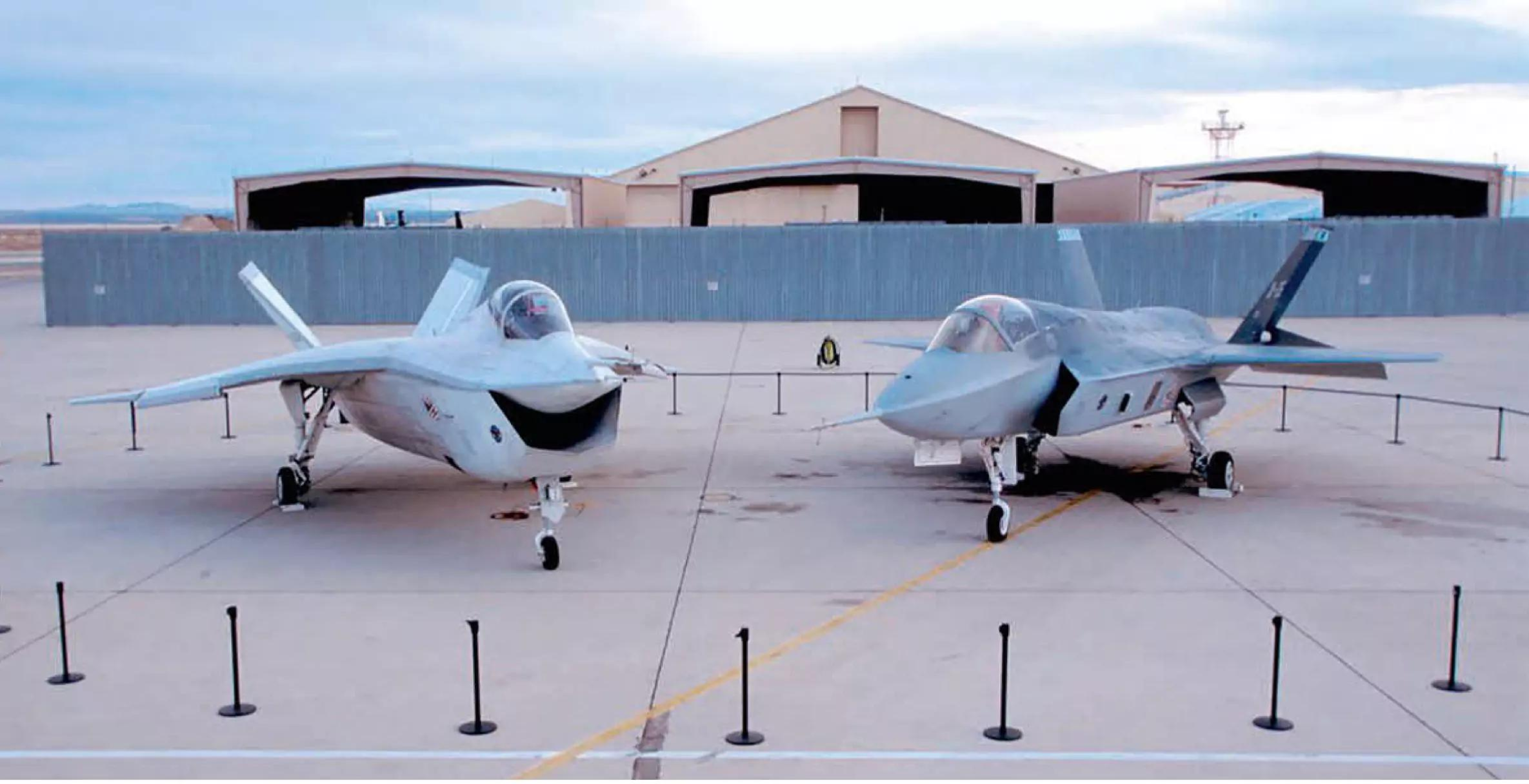
JAST was renamed the Joint Strike Fighter (JSF) programme in 1995 and the project now picked up speed. In the same year the US DoD issued its requirement for the new aircraft and received submissions from McDonnell Douglas, Northrop Grumman, Lockheed and Boeing. Then on November 16, 1996, Boeing and what was now Lockheed Martin were each awarded contracts to produce a pair of concept demonstrator aircraft (CDA). Under the contract, these experimental prototypes were required to demonstrate conventional take-off and landing (CTOL) and catapult-assisted take-off but arrested recovery (CATOBAR), as well as Short Take-Off and Vertical Landing (STOVL). Lockheed Martin built the X-35A (later converted to X-35B configuration) and X-35C demonstrators, while Boeing produced the X-32A and X-32B. Both were types embodied the features necessary for a high-performance aircraft, with Lockheed Martin's design making use of the of the Shaft Driven Lift Fan (SDLF) system, developed under the ASTOVL/CALF programme, enabling STOVL operation.

The SDLF placed a lift fan in the forward centre fuselage that could be activated by engaging a clutch connecting the driveshaft to the turbines, thus augmenting the thrust from the engine's swivel nozzle. Lockheed Martin's commonality strategy was to replace the STOVL variant's SDLF with a fuel tank and the aft swivel nozzle with a two-dimensional thrust-vectoring nozzle for the carrier variant.

The X-35A first flew on October 24, 2000 and conducted a series of flight tests. After 28 flights, the aircraft was duly converted into the X-35B and the shaft-drive fan, aft swivel and roll posts were added for STOVL testing. The X-35B successfully demonstrated the SDLF system by performing stable hover, vertical landing, and short take-off in less than 500ft. The larger-winged conventional take-off X-35C first flew on December 16, 2000 and conducted field landing carrier practice tests.

The US DoD declared Lockheed Martin the winner on October 26, 2001 and the company was awarded the System Development and Demonstration (SDD) contract. Aero-engine company Pratt & Whitney was separately awarded a development contract for what was termed the F115 engine. It was alleged that Boeing's X-32 lost the JSF contract due to a combination of technical issues and design compromises; while

The older brother to the F-35, the F-22 Raptor. **Picture US DoD**



The two competitors for the JSF programme, the Boeing X-32 and Lockheed Martin X-35. **Picture Lockheed Martin**

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The X-35B pictured hovering in place during tests. **Picture US Marines**

The F-35 will serve alongside the Navy's F/A-18E/F Super Hornets. **Picture US Navy**

the X-32 prioritised cost-saving and modularity, it struggled to adequately overcome practical challenges such as hovering stability.

The loss of the JSF contract to Lockheed Martin was a major blow to Boeing, as it represented the most important international fighter aircraft project at the time. However, Boeing viewed its work on the X-32 as a strategic investment, yielding important technologies which it has been able to adopt in the Boeing F/A-18E/F Super Hornet.

Then on March 21, 2025, US President Donald Trump announced that the engineering and manufacturing development contract for the sixth-generation fighter, designated the F-47 and worth more than $20 billion, would be awarded to Boeing. The F-47 is designed to be the successor to Lockheed Martin's F-22 Raptor. In mid-2025 USAF officials revealed that experimental tests had in fact been flown in the US since 2020, and the US military is aiming to field the F-47 by the end of the decade. The USAF plans to purchase approximately 200-250 F-47s to serve alongside a fleet of potentially nearly 1,800 F-35s.

Joint Strike Fighter

As the JSF programme moved into the System Development and Demonstration phase, the X-35 demonstrator design was modified to accommodate the full mission requirement of the F-35 combat aircraft. The forward fuselage was lengthened by 5in to make room for mission avionics, while the horizontal stabilizers were moved 2in to the rear in order to improve balance and control. The diverterless supersonic inlet (the air intake) changed from a four-sided to a three-sided cowl shape and was moved 30in to the rear. The fuselage section became fuller, the top surface was raised by one inch along the centreline and the lower surface was bulged to accommodate weapons bays. Following the designations applied to the X-35 prototypes, the three variants were designated F-35A (CTOL), F-35B (STOVL), and F-35C (CV).

Prime contractor Lockheed Martin performed overall systems integration, final assembly and checkout at a factory known as Air Force Plant 4 in Fort Worth Texas, while Northrop Grumman and BAE Systems supplied components, mission systems and airframe parts. BAE in the UK manufactured and built the rear fuselage for the F-35. Adding the necessary fighter aircraft systems added weight, which impacted on the proposed performance of the aircraft. In December 2003, Lockheed Martin formed the STOVL Weight Attack Team (SWAT) to tackle this problem and their work would eventually see changes to the B variant's overall airframe, with smaller weapons bays and vertical stabilizers and less thrust fed to the roll-post outlets. The wing-mate joint was redesigned as well as electrical elements and the airframe immediately aft of the cockpit. By September 2004, these efforts had reduced the F-35B's weight by over 3,000lb, while the F-35A and F-35C were reduced in weight by 2,400lb and 1,900lb respectively. The weight reduction work, while essential, cost $6.2 billion and caused an 18-month delay.

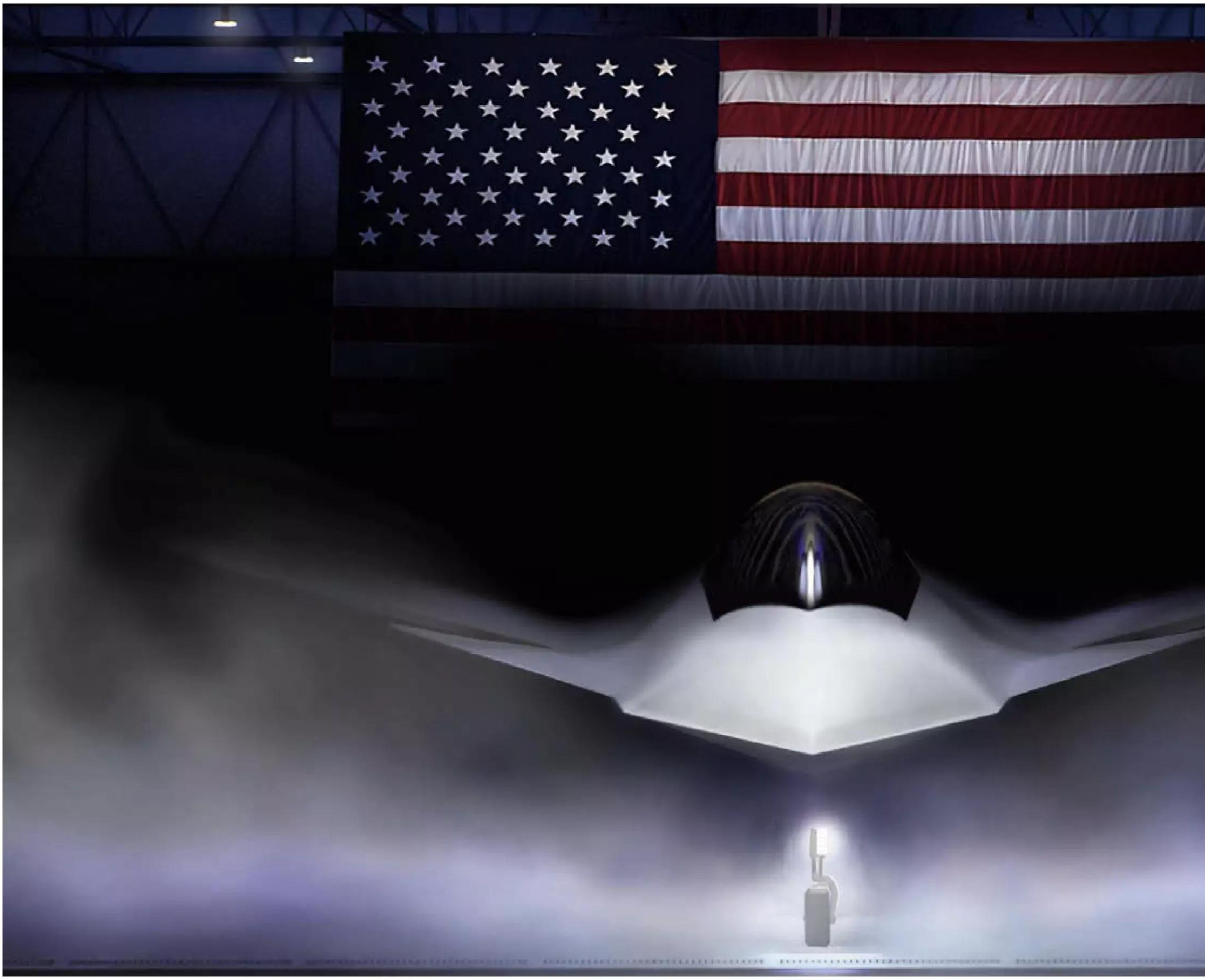
The F-35 is powered by a single Pratt & Whitney turbofan, the F135, which delivers sufficient power to take the

The US Marines' F/A-18 fleet has been wound down as the F-35 has come into service. **Picture US Navy**

The Boeing X-32 lost to Lockheed's X-35. **Picture Boeing**

The Harrier AV-8B fleet operated by the US Marines will be replaced by the STOVL F-35B. **Picture US Marines**

The USAF's F-16s are being replaced by the conventional take-off F-35A. **Picture USAF**



The F-47 is being developed as America's 6th generation fighter, replacing the F-22 and working alongside the F-35. **Picture US DoD**

aircraft to 1,200mph. Derived from the F119 engine used in the F-22 Raptor, the F135 has a larger fan to aid the delivery of subsonic thrust and better fuel efficiency. The engine contributes to the F-35's stealth by having a low-observable afterburner that incorporates fuel injectors into thick curved vanes which are covered by ceramic radar-absorbent materials and mask the turbine. Due to the engine's large dimensions, the Navy had to modify its underway replenishment system to facilitate at-sea logistics support.

The F-35's Integrated Power Package (IPP) performs power and thermal management and combines environment control, auxiliary power unit, engine starting and other functions into a single system. The UK engine manufacturer Rolls-Royce delivers the F135-PW-600 variant for the F-35B, which incorporates the Shaft-Driven Lift Fan (SDLF) to allow STOVL operations. Unlike the Harrier's Pegasus engine that entirely uses direct engine thrust for lift, the F-35B's system augments the swivel nozzle's thrust with the lift fan; the fan is powered by the low-pressure turbine through a drive shaft when engaged with a clutch and is placed near the front of the aircraft to provide a torque countering that of the 3BSM nozzle. Roll control during slow flight is achieved by diverting unheated engine bypass air through wing-mounted thrust nozzles called roll posts.

The combat capabilities of the F-35 are made possible through software developments to advance functionality. What is known as Block 2B software enables F-35 pilots to provide basic close air support with both the Joint Direct Attack Munition (JDAM) and the 500lb Guided Bomb Unit (termed the GBU-12 Paveway II), as well as firing the AIM-120 AMRAAM air-to-air missile. The upgrade to Block 3F software extends that capability to suppress enemy air defences and enables the Lightning II to deploy the GPS-directed 'Stormbreaker' munition (designated the GBU-53/B SBD II) and the AIM-9X Sidewinder air-to-air missile.

The first test flight of the Lockheed Martin F-35 Lightning II (F-35A) took place on December 15, 2006, flown by Lockheed Martin Chief Test Pilot Jon S. Beesley. The prototype, AA-1, lifted off from Fort Worth and reached an altitude of 15,000ft at a speed of 259mph. After this initial flight, Beesley said: "The Lightning II performed beautifully.

What a great start for the flight-test programme, and a testimony to the people who have worked so hard to make this happen."

The F-35B entered service with the USMC in July 2015, followed by the USAF with the F-35A in August 2016 and the US Navy (F-35C) in February 2019. The United Kingdom was naturally the first foreign state involved in the JSF programme, followed by Italy, the Netherlands, Denmark, Norway, Canada and Australia. Turkey was also a participant of the programme, but had its JSF privileges revoked by Washington after refusing US demands to not acquire the Russian-made S-400 air-defence system for security reasons. Israel became the first country to select the F-35 through the United States Government's Foreign Military Sales (FMS) process when a Letter of Agreement was signed in October 2010.The Israeli Air Force (IAF) gave the F-35 the name Adir, meaning 'Mighty One' in Hebrew.

On June 22, 2016, the IAF received the first F-35I Adir. The IAF's F-35 fleet was declared operationally capable in December 2017, marking the completion of an intensive integration and training effort conducted at Nevatim air force base in Israel. Israel's F-35I is unique due to its specialist adaptations for the Middle Eastern theatre, including integration with Israeli-made command and control (C4I) systems, tailored electronic warfare capabilities, indigenous weapons and extended range options. These modifications, alongside a unique sustainment and upgrade system, allow Israel to refine and enhance the aircraft's performance independently.

Made to evade

Lockheed Martin's engineers studied and embraced decades of painstaking in-house research to deliver the F-35's stealth capabilities. The radar cross-section (RCS) is minimised through careful shaping of the airframe and the use of radar absorbent materials (RAM). In addition, visible measures to reduce RCS include alignment of edges and continuous curvature of surfaces, serration of skin panels, and the masking of the engine face and turbine.

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First flight of the first produced F-35 as part of the Joint Strike Fighter Program. **Picture US DoD**

An F-35C Prototype in flight; the 'C' variant is dedicated to aircraft carrier operations. **Picture US DoD**

Additionally, the F-35's DSI – a type of jet engine air intake used by some modern combat aircraft to control air flow into their engine – is a compression bump and forward-swept cowl, rather than a splitter gap. This 'splitter gap' is the usual way of diverting the boundary layer (the thin layer of turbulent air that forms around the surface of a fast-moving aircraft) away from the inlet duct. The use of a compression bump and forward-swept cowl helps reduce the aircraft's heat signature.

The RCS of the F-35 has been characterised as lower than a metal golf ball at certain frequencies and angles. In some conditions, the F-35 compares favourably to the stealth capability of the F-22, while the F-35's 'radar-absorbent fibermat skin' is more durable and requires less maintenance. The aircraft also has reduced infrared and visual signature as well as strict controls of radio frequency emitters to prevent their detection.

The F-35's stealth design is primarily focused on high-frequency X band wavelengths. Low frequency radars can spot stealthy aircraft due to what is called Rayleigh scattering, the process of deflecting light or electromagnetic radiation within small particles. To disguise its radar cross section, the

F-35 pilots undergo simulator training to prepare them for live flight and to ensure their skills are up to date. **Picture USAF**

Every F-35 pilot has their high-tech lightweight helmet custom-fitted during a two-day process. **Picture Lockheed Martin**

aircraft can mount four Luneburg lens reflectors across its frame. The refractive index of a typical Luneburg lens decreases radially from the centre to the outer surface, helping to reduce the radar signature of the F-35.

The F-35 can perform ground-attack, aerial reconnaissance and air defence missions, and using its advanced stealth and sensors, it can detect enemy aircraft long before being detected. The plane's conventional probes and vanes are housed internally and its external shape, internal carriage of weapons, fuel and embedded sensors are all designed for maximum stealth performance. This is an aircraft that was made to evade.

The pilot's cockpit is revolutionary, promoted by Lockheed Martin as 'being designed for total mission success' and claimed to be the most survivable yet lethal cockpit environment ever produced.

It features a speech recognition system developed by Adacel. The one-piece tinted canopy is hinged at the front and has an internal frame for structural strength. The US16E ejection seat, produced by Martin-Baker, the world's leading ejection seat company, is launched by a twin-catapult system housed on side rails. The system is fitted with an onboard oxygen-generation system, known as OBOGS, which provides an auxiliary oxygen bottle and backup oxygen system for emergency use.

The AN/AAQ-37 Distributed Aperture System (DAS) fitted to the F-35 is the first of a new generation of sensor systems and consists of six high-resolution infrared sensors mounted around the airframe. They provide unobstructed spherical coverage and

The Royal Navy has procured F-35Bs for its aircraft carriers. **Picture UK MoD**

F-35C, the aircraft carrier variant, makes an arrested landing. **Picture US Navy**

F-35B makes a vertical landing on a US Navy assault ship. **Picture US Navy**

Another F-35C makes an arrested landing on the deck of a carrier. **Picture US Navy**

F-35A at speed during low-level tactical training. **Picture USAF**

operate around the aircraft without any pilot input and are key to the enhanced situational awareness. The Vision Systems International helmet display is a key piece of the F-35's human-machine interface. Instead of the head-up display mounted on the dashboard of earlier fighters, the helmet display puts flight and combat information on the helmet visor, allowing the pilot to see it no matter which way he or she is facing. The DAS sensors provide both infrared and night vision imagery to the Helmet Mounted Display Screen (HMDS) and enable the pilot to 'see through' the aircraft. The HMDS allows an F-35 pilot to fire missiles at targets even when the nose of the aircraft is pointing elsewhere. Each helmet costs $400,000 – making it the most expensive pilot's helmet in the world. The HMDS weighs more than traditional helmets, and there is concern that it could endanger lightweight pilots during ejection.

Since its inception, the F-35 Lightning II has been a cornerstone of military aviation technology. With the introduction of the Block 4 upgrade, the aircraft is undergoing a significant transformation through substantial hardware and software enhancements, fundamentally altering its operational capabilities. Rather than

merely addressing gaps or adding minor features, this update represents a comprehensive evolution of the platform. The Block 4 modernisation programme began in 2018 with the goal of integrating 75 new features. These include advanced maintenance diagnostics, enhanced communication capabilities, new weapons integration, and software upgrades aimed at addressing existing limitations. However, the programme has faced delays due to challenges in developing and integrating new technologies. Issues such as supply chain disruptions and extended testing schedules have affected the Technology Refresh 3 (TR-3) configuration, a critical component of Block 4.

Despite these hurdles, deliveries of F-35 aircraft equipped with TR-3 resumed in July 2024.The serves as the backbone of the Block 4 upgrade. It introduces an open mission systems architecture, a next-generation integrated processor with significantly increased computing power, an enhanced panoramic cockpit display and expanded memory. These upgrades deliver computing capabilities 25 times greater than earlier configurations, ensuring the aircraft remains capable of addressing evolving threats. Key hardware improvements include the integration of the AN/APG-85 radar, which replaces the AN/APG-81. This active electronically scanned array (AESA) radar enhances target detection and tracking, improving the pilot's situational awareness. Additionally, the propulsion system is being upgraded through Pratt & Whitney's F135 Engine Core Upgrade (ECU), which aims to enhance durability, performance and lifecycle cost efficiency. The Block 4 programme introduces over 75 major updates across all three F-35 variants. These include increased payload capacity, advanced electronic warfare (EW) capabilities and enhanced target recognition. Collectively, these upgrades aim to improve lethality, survivability and overall mission effectiveness. The F-35's payload capacity has been increased to 18,000lb (8,200kg), expanding its operational versatility. Newly integrated weapons include the AIM-260 Joint Advanced Tactical Missile (JATM), the AGM-158C Long-Range Anti-Ship Missile (LRASM), and other systems under development, such as SPEAR 3. These additions further enhance the aircraft's capability for air superiority, interdiction and deep strike missions.

Heat, which can easily be identified by enemy surveillance is a major concern to F-35 engineers as it is one of the factors in reducing the fighter's radar footprint. The more upgrades the aircraft's computers receive, the harder the task of keeping the system cool. Imagine your office or home computer is overloaded with open files or you decide to fit a new operating system without installing additional RAM. The computer will get hot and sluggish, and that is the dilemma facing F-35 engineers. The TR-3 major upgrade will deliver improvements to the aircraft's hardware and software, as well as providing more computer memory and processing power. It is this additional processing capability that creates heat and requires further solutions from engineers to keep the aircraft cool. ■

2

CHAPTER

The F-35A Variant

The F-35A is the variant operated by the United States Air Force (USAF) in the conventional take-off and landing version of the fifth-generation fighter. It has been introduced to replace the USAF's General Dynamics F-16 Fighting Falcon and Fairchild Republic A-10 Thunderbolt II, both of which have been in service for more than four decades. It is also the variant most widely purchased by overseas customers – with whom it most commonly replaces legacy F-16s.

The arrival of the first F-35A into service in August 2016 gave the USAF a level of air superiority unrivalled by either China or Russia. In early April 2019, four F-35As deployed to Al Dhafra air base in the United Arab Emirates. On April 27, these aircraft mounted their first combat operation in an airstrike on an Islamic State tunnel network in northern Iraq.

The F-35A is the most common variant of the fighter, designed for conventional take-off and landing. **Picture USAF**

Inside the cockpit, the F-35A pilot navigates using an advanced helmet-mounted display system that fuses data in real time. **Picture US DoD**

First mission

The 34th Fighter Squadron (34th FS) at Hill Air Force Base, Utah, became the first operational F-35A Lightning II squadron in August 2016 and quickly achieved initial operational capability. The squadron underwent an evaluation exercise, codenamed Combat Hammer, at Eglin Air Force Base, Florida, where they used the GBU-49 laser guided bomb for the first time in F-35A combat training.

Combat Hammer was seen as a validation test for operational deployment, with training on the Utah test range using live and inert GBU-49s.This GPS-directed bomb can be used in a variety of conditions against many types of moving or stationary targets. During the exercise, teams also assessed the readiness of weapon crews, the maintainers who fit the munitions.

Within weeks the 34th FS, known as the 'Rude Rams' reached full operational capability and in 2019 deployed to the Middle East for Operation Inherent Resolve, which would become the first combat deployment of the F-35A against insurgents in Iraq. Intelligence reports indicated that Islamic State was using tunnels deep in the Hamrin Mountains, a small mountain ridge in northeast Iraq known to be home to insurgents.

From deep strike to air interdiction, the F-35A can support aircraft such as the B-2 Spirit, stealth bomber, in an escort role. **Picture USAF**

The F-35A multirole fighter aircraft, designed to replace older aircraft like the F-16 and A-10 and is one of three variants in the F-35 family. **Picture USAF**

A cloud of vapour trails behind as the F-35A punches through the sound barrier during high-speed flight tests. **Picture USAF**

At the westernmost ripple of the Zagros Mountains, the Hamrin Mountains extend from the Diyala Governorate bordering Iran, northwest to the Tigris River, crossing the province of northern Saladin and across to southern Kirkuk. It was a remote area, hard to access and at the time US Central Command, the headquarters group responsible for operations in the Middle East, Central Asia and parts of South Asia said the identified target was "an insurgent weapons cache at Wadi Ashai and a tunnel network in Iraq's Hamrin mountain range".

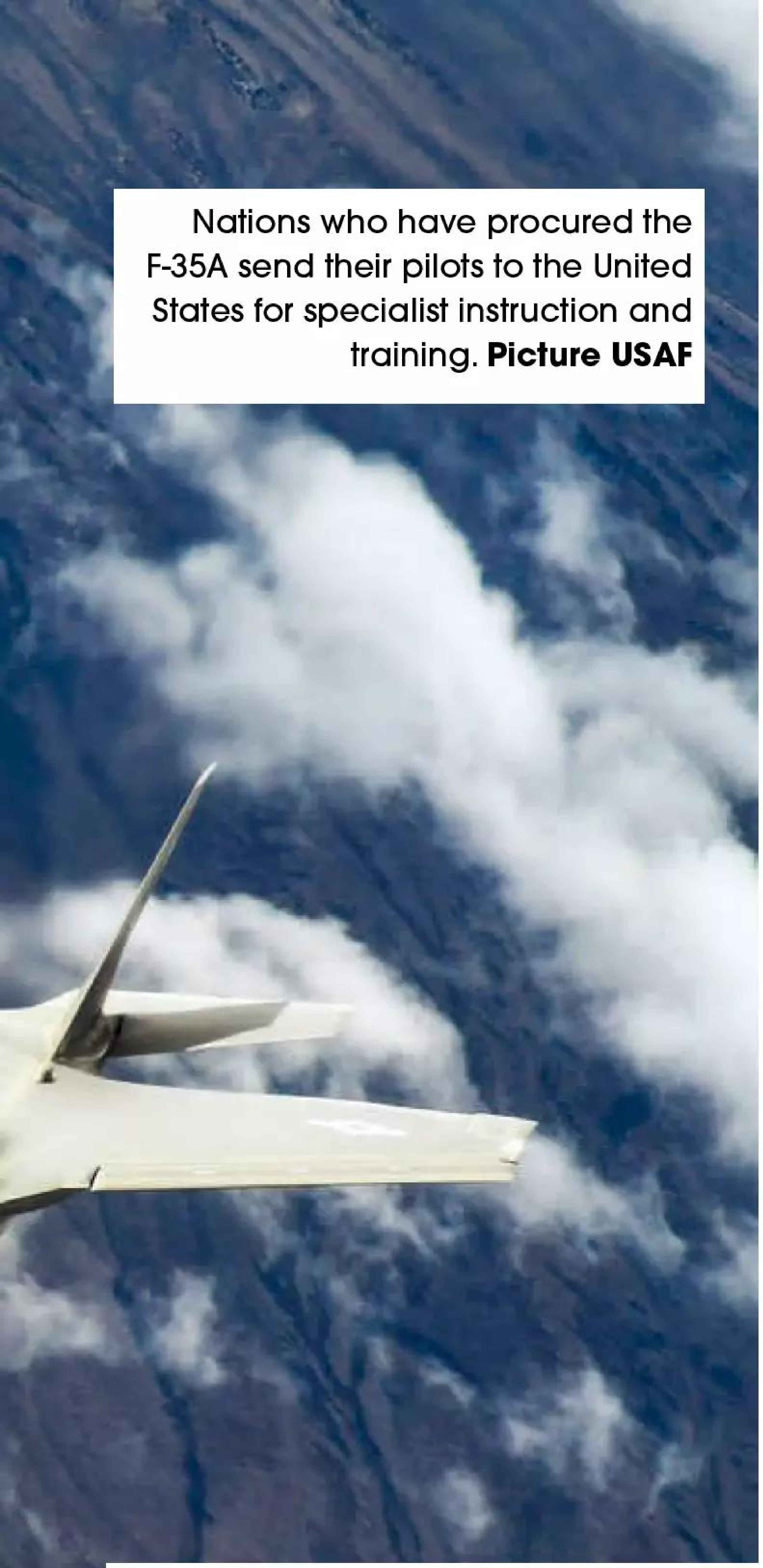
The mission required detailed planning to ensure a successful strike and selection of the correct munitions was crucial. A decision was made that two F-35As would each drop a Joint Directed Attack Munition (JDAM) on the target; these 'bunker busters' are regular unguided 'dumb' bombs but fitted with kit which includes a GPS-based guidance system and a steerable tail fin kit.

Prior to launch, the pilot enters the GPS coordinates of the target into the system. On release the munition then steers itself towards the target, the GPS making it typically accurate to within 12ft.

At the time, Staff Sgt Karl Tesch, a senior engineer with the 380th Expeditionary Aircraft Maintenance Squadron, which provided weapons support to the F-35As of the 34th FS, said: "This jet is smarter, a lot smarter, and so it can do more, and it helps you out more when loading munitions. The F-35A has sensors everywhere, it has advanced radar, and it is gathering and fusing all this information from the battlespace in real time."

Danger to the aircraft during the mission was minimal since Islamic State had few if any surface-to-air weapons and had never shot down a single plane.

Integrated seamlessly into coalition forces, the F-35A shares real-time intelligence across allied platforms. **Picture USAF**



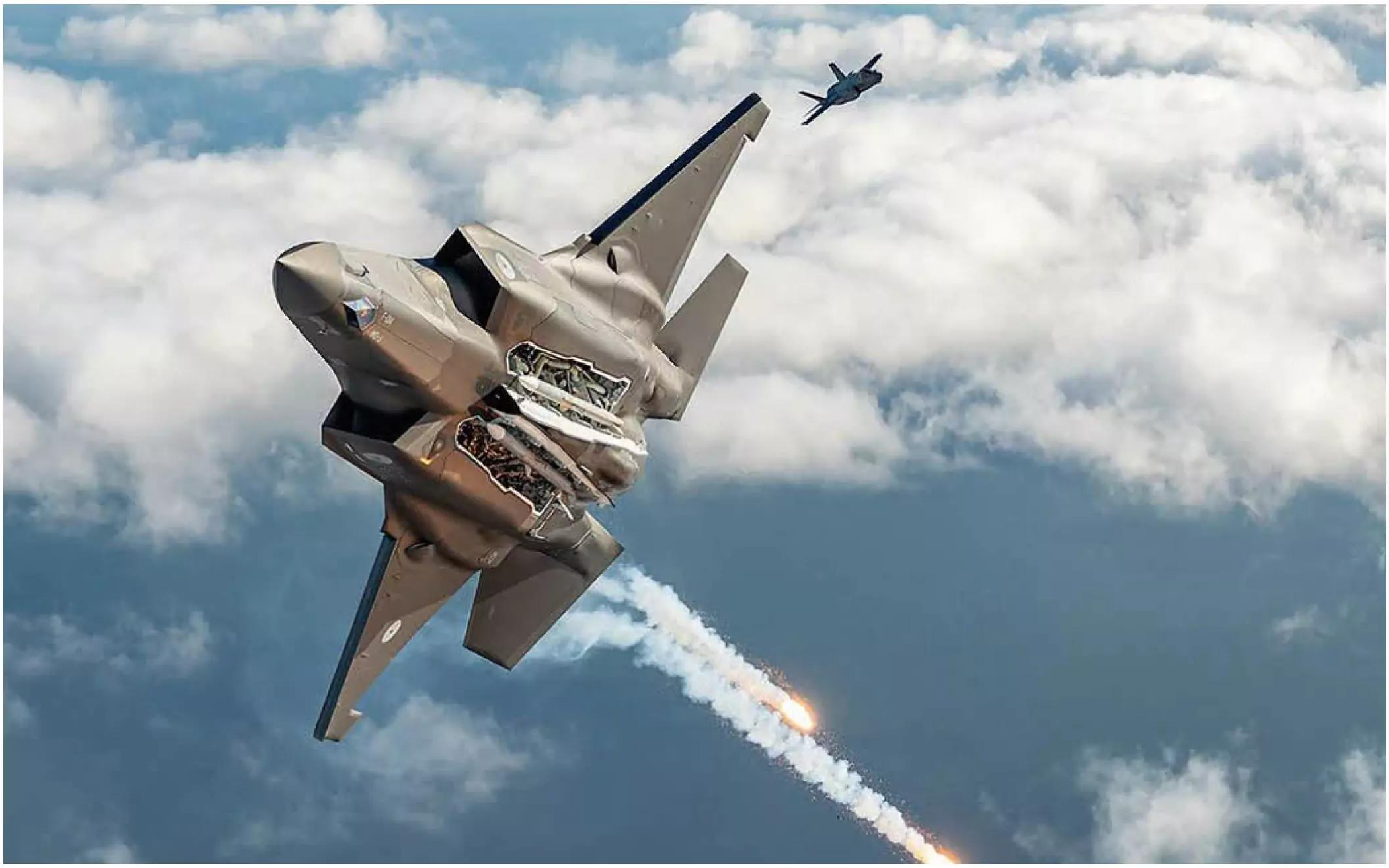
Nations who have procured the F-35A send their pilots to the United States for specialist instruction and training. **Picture USAF**

The F-35A forms a critical component of the United States Air Force's 5th-generation fighter fleet, bridging today's missions with tomorrow's threats. **Picture US DoD**

The USAF F-35A mission came a year after an F-35B serving with the US Marines bombed both Islamic State and Taliban fighters, having deployed from the amphibious assault ship USS *Essex*. And prior to that engagement, the Israel Defence Force (IDF) had become the first country to use the F-35 in combat when, in May 2018, the IDF's F-35A variant, the F-35I Adir, conducted airstrikes in Syria. Israel's then-air force chief showed an image of IDF F-35Is over Beirut, Lebanon, and said the planes had "already attacked twice on two different fronts".

Replacing the A-10

The multirole F-35A is the CTOL (conventional take-off and landing) version – it is also the variant that is closest in design to what might be regarded as a conventional fighter.



The F-35A's internal weapons bay can be seen open in mid-flight, revealing a payload of precision-guided munitions. **Picture USAF**

A Dutch F-35A Lightning II, operating from Edwards Air Force Base, conducts cannon trials. **Picture US DoD**

Several NATO nations operate the F-35 contributing to the collective defence of the Alliance through air policing missions. **Picture USAF**

Experience with the F-4 Phantom II in Vietnam, which had initially been armed only with missiles, taught the USAF the importance of carrying a gun for close-in dogfighting. Therefore, the F-35A is the only variant equipped with a 25mm GAU-22/A four-barrel rotary cannon. This gun is mounted internally above the left engine intake and is flush mounted to maintain the aircraft's stealth profile. It has a rate of fire of 3,300 rounds per minute and is fed from a 180-round magazine – meaning that just a few seconds of fire are available during an engagement.

While the F-35A's internal cannon is primarily intended for use during close-range air-to-air engagements, it can also be used during air-to-ground close support missions. Despite its limited ammunition capacity, the cannon is part of a defined plan to replace and retain the A-10's gatling gun capability in engaging ground targets.

The Fairchild Republic A-10 Thunderbolt II, universally known in practise as the 'Warthog', which entered service in October 1977, is a heavily-armoured low-speed dedicated close-support platform powered by two podded General Electric TF34-GE-100A turbofans mounted above its rear fuselage. Its most famous feature, however, is its single 30mm GAU-8/A Avenger rotary cannon with 1,174 rounds – which is capable of destroying enemy tanks and shredding softer-skinned vehicles, emplacements and enemy troops.

As a replacement for the A-10, the F-35A is required to excel in three mission areas – close air support (CAS), forward air controller (FAC) and combat search and rescue (CSAR) – in low-threat 'permissive' and medium threat 'contested' environments.

It has to be able to attack armoured vehicles, tanks, installations and enemy troops using a variety of forward-firing guided and unguided weapons, sensors and communications systems.

In order to demonstrate its ability to succeed the A-10, F-35As were flown in comparative tests with USAF A-10Cs during six 'test events' at Edwards AFB, Nellis AFB and the China Lake range. The CAS tests took place at Edwards AFB from July 6-12, 2018; the FAC tests from July 11-18, 2018, and March 26-28, 2019, and the CSAR tests from April 3-5, 2018; July 10-11, 2018 and March 25-27, 2019.

During the CAS tests, both types were flown as two-ship formations with either a FAC or ground-based Joint Attach Controller serving as the tasking

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The F-35A and other variants are viewed by the US military as 'force multipliers' due to their advanced electronics and communications systems. **Picture USAF**

An F-35A awaits pre-flight checks, its radar-absorbing coating shimmering in the sun. **Picture USAF**

authority – briefing the formation on their target and clearing them to initiate the attack.

For testing in the FAC role, liaising with CAS formations, the F-35As and A-10Cs were again flown in two-ship formations controlling F/A-18s, F-16s or F-35As as the CAS aircraft.

CSAR operations are generally conducted to recover friendly personnel, normally downed aircrew, and the complexity of the mission can depend on a wide range of factors including threats, environmental conditions and what recovery assets are available. During these exercises, the F-35As and A-10Cs were flown in four-ship formations and had to escort recovery aircraft, locate and positively identify the downed aircrew and secure the area of operations before and during the rescue.

While the results of the tests remain largely classified, a partial report has been made available thanks to Freedom of Information legislation. In the CAS role, it was unsurprisingly found that "the typical loadout of the A-10C enabled more attacks than the typical loadout of the F-35A, particularly in the contested threat environment".

The F-35As apparently also had greater difficulty in locating their targets. The report noted that "tactics typically caused A-10C pilots to fly closer to the target than F-35A pilots, which could explain some of the difference in the measured location errors. Target location error only affects the use of GPS-aided weapons. In any case, the location error is sufficient to cue another CAS aircraft's targeting pod".

In the F-35A's defence however, it was reported that "increased numbers of more capable, modern threat systems or the addition of an air threat would likely result in the need to dedicate additional aircraft to suppression and destruction and counter-air roles, either pre-emptively or concurrent with CAS. Trials in such an environment could yield important lessons, but the F-35A has a clear capability advantage over the A-10C in higher threat environments – an environment where the A-10 was not designed to operate".

In other words, while the A-10C had the upper hand in low-threat environments, it would need increasing levels of support from additional aircraft when the threat increased – whereas the F-35A was able to cope with rising threat levels without having to rely on reinforcements.

F-35A and F-16 fighters take part in an 'Elephant walk' – the taxiing of military aircraft en masse before taking off in single-file formations. **Picture USAF**

When operating in a group of four each aircraft is configured for different roles such as strike, suppression, surveillance and overwatch. **Picture USAF**

When it came to operating in the FAC role, "A-10C pilots reported a significantly lower workload than F-35A pilots in the task-intensive FAC mission". The rest of this section of the report was redacted.

Lastly, for CSAR, "a frequent comment by both F-35A and A-10C pilots during debriefings was the synergies that would occur if A-10C formations operated with F-35C escort during contested CSAR missions. This would combine the strengths of both platforms while mitigating their limitations to improve the likelihood of mission success".

This was perhaps not what those at the top, particularly those holding the purse strings, would wish to hear – that the F-35A works better in practise in support of dedicated ground-attack aircraft, rather than being the ground-attack aircraft itself.

The USAF had received congressional permission to start retiring its A-10s in 2023, but further retirements were then paused until the USAF could demonstrate that the A-10's CAS capabilities can be replaced.

Replacing the F-16

The comparison between the F-35A and the F-16s operated by the USAF and many overseas F-35 customers is somewhat more clear cut – with the former surpassing the latter in nearly every respect.

The General Dynamics F-16 Fighting Falcon, commonly known as the Viper, entered operational service with the USAF in January 1979 and was a huge export success, with customers including but not limited to Israel, Egypt, The Netherlands, Belgium, Denmark, Norway, Pakistan and Turkey.

The F-16's single General Electric F110 engine generates 27,000lb of thrust but the F-35A's Pratt & Whitney F135 can provide 43,000lb. The F-16 can carry 7,000lb of fuel internally and a total of 12,000lb with two external drop tanks, whereas the F-35A's internal fuel capacity alone is 18,498lb – resulting in a big range and endurance advantage for the stealth aircraft. In terms of payload, the F-16 can carry up to 16,600lb but the F-35A can manage up to 18,000lb.

The F-16 – designed and built before stealth aircraft had become a practical proposition – has essentially no stealth features, whereas a key feature of the F-35A's design is its very much geared towards low observability. It's not invisible, but this capability significantly reduces the distance at which it can be detected by enemy radar.

The two aircraft share an operational ceiling of 50,000ft and the F-16 has a top speed of Mach 2 while the F-35A tops out at Mach 1.6 – but outright speed isn't everything.

An F-35A assigned to the 58th Fighter Squadron, 33rd Fighter Wing (FW) at Eglin Air Force Base, flies low-level over the coast of Fort Walton Beach in Florida. **Picture USAF**

USAF F-35As assigned to the 58th Fighter Squadron, 33rd Fighter Wing fly in formation as they prepare to take fuel from a KC-135 Stratotanker. **Picture USAF**

Royal Norwegian Air Force pilot Major Morten 'Dolby' Hanche, who flew many mock dogfights immediately after becoming his nation's first F-35A pilot, wrote on his blog in 2015: "So how does the F-35 behave in a dogfight? The offensive role feels somewhat different from what I am used to with the F-16. In the F-16 I had to be more patient than in the F-35, before pointing my nose at my opponent to employ weapons; pointing my nose and employing, before being safely established in the control position, would often lead to a role reversal, where the offensive became the defensive part. When I push the stick forward, the F-35 reacts immediately and not delayed like the F-16.

"The F-35 provides me as a pilot greater authority to point the nose of the aircraft where I desire (the F-35 is capable of significantly higher angle of attack than the F-16). This improved ability to point at my opponent enables me to deliver weapons earlier than I am used to with the F-16; it forces my opponent to react even more defensively, and it gives me the ability to reduce the airspeed quicker than in the F-16."

F-35 test pilot Monessa Balzhiser, callsign 'Siren', who spent years flying F-16s with the USAF, also highlighted the F-35's high angle of attack capability as a major advantage when speaking to *Business Insider*: "The high angle of attack that the F-35 can perform was what caught me off guard coming from the F-16." She said that the F-16 had always been renowned for its speed and turn rate but "all the flight controls and the computer that runs the flight controls on the F-35 allow me to intercept – on the same mission – a slow, low Cessna going 80 knots to a high, fast flyer going Mach 1.2".

In addition, the F-35's cockpit systems, including that expensive helmet, presented huge amounts of information to the pilot in a way that gave unprecedented situational awareness, whereas with the F-16, "we had some of that information, but it was all shown on multiple different displays or formats".

It is worth noting, however, that where the F-16E/F costs around $50m to purchase, the F-35A is said to cost between $110-130m – so the additional capability is not without cost.

Beast mode

While the F-35A was carefully designed with a smooth and seamless exterior in order to defeat enemy radar, it doesn't have to be used that way. The Israeli Air Force is known to regularly operate its F-35A-based F-35Is in so-called 'Beast mode', whereby heavy munitions are attached on underwing pylons in addition to stores carried in the aircraft's internal weapons bays.

In particular, Israel has developed the ability to launch JDAMs from the aircraft's four underwing pylons. While the IAF's exact specification for this arrangement is unclear, photos have been released showing an instrumented F-35I carrying four external GBU-31 JDAMs with a single AIM-120 AMRAAM air-to-air missile in one of the internal bays – which may also house another internal JDAM.

Details remain sketchy due to Israel's general reticence about releasing such information, but it is known that the IAF's F-35Is have seen extensive combat since October 2023 – including attacks on targets in Gaza and Lebanon and against Iranian-backed Houthi militants in Yemen and against Iran itself.

While carrying external stores does erode the F-35's stealth characteristics considerably, it also makes the aircraft a highly versatile platform particularly in relatively low-threat environments where stealth is unnecessary and a 'bomb truck' is what the situation requires.

It has also been suggested that Israel may have been increasing the range of its F-35Is by fitting a flush-mounted conformal external fuel tank – or alternatively housing some sort of extra fuel tank within their weapons bays. These developments will undoubtedly have been implemented with the full support of manufacturer Lockheed Martin. The company's own literature states that: "In stealth mode, the F-35 can infiltrate enemy territory that

A USAF F-35 from the 493rd Fighter Squadron arrives at Šiauliai air base in Lithuania for exercises over Latvia and Lithuania. **Picture US DoD**

F-35As pictured during an exercise over Arizona where pilots undergo weeks of training. **Picture USAF**

The F-35 is currently in service with 20 countries across Europe and the Far East. **Picture USAF**

The arrival of the first F-35A into service in August 2016 gave the USAF a level of air superiority unrivalled by either China or Russia. **Picture USAF**

• F-35A Lightning II

Function: Multirole fighter
Prime contractor: Lockheed Martin
Crew: One
Power plant: 1 x Pratt & Whitney F135-PW-100 turbofan engine
Thrust: 43,000lb
Wingspan: 35ft
Length: 51ft
Height: 14ft
Maximum take-off weight: 70,000lb
Internal fuel capacity: 18,498lb
Payload: 18,000lb
Speed: Mach 1.6 (1,200mph)
Range: More than 1,350 miles with internal fuel (1,200+ nautical miles), unlimited with aerial refuelling
Ceiling: Above 50,000ft
Armament: Internal and external capability. Munitions carried vary based on mission requirements

other fighters can't, carrying 5,700lb of internal ordnance. Once air dominance is established, the F-35 converts to beast mode, carrying up to 22,000lb of combined internal and external weapons, to return to the battle to finish the fight."

Indeed, it is certain is that other F-35A operators will have been watching these developments closely and will be considering their own options for 'beast mode'.

Spy plane

While the F-35A wasn't designed primarily for use in intelligence gathering, it can certainly be used to do exactly that. It features an AAQ-40 Electro-Optical Targeting System – a thermal infrared camera derived from Lockheed's own SNIPER XR targeting pod which has a very high optical zoom function. This allows an F-35A pilot to capture imagery of a target – though it only sees in the mid-wave infrared spectrum so it isn't very good for picking out different colours.

In addition, the F-35A's APG-81 active electronically scanned array radar allows it to generate synthetic aperture maps. These aren't as detailed as you would get from a photograph but the system can see through clouds and is excellent at highlighting metallic objects such as hidden tanks. These maps can also be rendered in 3D, which means even features such as areas of grass flattened by vehicles can be identified.

The ASQ-239 Barracuda electronic warfare suite can be used to geolocate the source of radio and radar signals without having to be aimed since it's constantly in use. And the AAQ-37 Distributed Aperture System – a set of six cameras – provides full coverage in a sphere around the aircraft. While it is only intended for short-range use, this can detect objects much further away if they are bright or hot enough – such as rocket launches.

Achilles' heel?

Despite its undeniable world-leading capabilities, the F-35's greatest weakness may be its reportedly poor availability. According to the 2023 financial year report of the US military's Director Operational Test and Evaluation on the F-35, the aircraft breaks down more often than anticipated and it takes longer than expected to repair it.

And while Lockheed Martin has been forging ahead with production of new airframes, a shortage of spare parts for those aircraft already in service has tended to leave many grounded and awaiting components such as new canopies, new sensor systems, new nacelle vent fans and numerous other parts, including engine spares.

The goal originally set for availability of the F-35 was 65% but for a 12-month period ending in September 2023, the average US fleet-wide monthly availability rate was just 51% – with this being a flat trend, rather than an averaging out of peaks and troughs in the data. By a different metric known as Full Mission Capable – the aircraft not just being available but being fully ready for action – the readiness rate for the whole US F-35 fleet during the same period was 30%. The rate for the operational test fleet was found to be as low as 9%.

Time will tell whether this shortfall in availability can be remedied as the system continues to mature and the supply chain and maintenance infrastructure associated with the programme continues to accumulate and improve. ■

3

CHAPTER

The F-35B Variant

The F-35B Lightning II was designed as a replacement for the successful vertical-lift Harrier in all its remaining variants – from the AV-8B Harrier IIs of the US Marines to the Sea Harriers operated by the Royal Navy and the RAF in the form of GR5, GR7 and GR9. In order to deliver the required short take-off and vertical landing (STOVL) capability, the F-35B is necessarily the most complex and consequently the most expensive of the three variants produced by Lockheed Martin.

Using an innovative vectored thrust and lift-fan configuration, it can take-off from a ship's flight deck without a catapult, often over a short distance, and land back on board vertically from the hover, allowing it to operate from almost anywhere. The F-35B entered operational service with the USMC in July 2015 and with the UK in June 2018. And the first USMC combat strikes using the aircraft took place in 2018 against Taliban targets in Afghanistan and ISIS in Syria.

A third operator, the Italian Navy, announced that it had achieved initial operational capability (IOC) with its F-35Bs – again replacing Harriers – in August 2024.

The F-35B Lightning II is the US Marine Corps variant of the Joint Strike Fighter and features a vertical lift fan and pivoting engine nozzle to support its STOVL capability. **Picture USMC**

Genesis of STOVL

The Hawker Siddeley Harrier, popularly known as the 'jump-jet' thanks to its vertical take-off and landing (VTOL) capability, had been a game changer for both US and UK forces. The concept of a VTOL aircraft evolved after the introduction of the helicopter and the events of the Suez Crisis in Egypt in 1956. It was here that the Royal Marines had made their first helicopter assault, flying ashore from the aircraft carrier HMS *Theseus*. The helicopter, although operating a totally different technology, had demonstrated the ability to mount offensive operations without the need for a fixed runway.

By the late 1950s, the United States and a number of countries in Europe were actively investigating options for a VTOL fixed-wing aircraft that would eliminate the need for runways. British firm Bristol Aero Engines designed an innovative vectored thrust engine, while a second UK company, Hawker Siddeley Aviation (HSA), was working on airframe designs that could meet a NATO specification for what was then called the 'Light Tactical Support Fighter'.

Bristol's projected vectored thrust engine, which they called Pegasus, harnessed rotatable 'cold' jets which were positioned on either side of the compressor, along with a 'hot' jet which was directed via a conventional central tailpipe. In 1957, HSA project engineer Ralph Hooper established an initial layout for a theoretical VTOL aircraft to take advantage of the Pegasus engine, using data provided by Bristol.

Then in March 1959, the Hawker Siddeley company decided to privately fund a pair of prototypes to demonstrate the design's capability, which received the internal designation P.1127. The Ministry of Supply issued a formal contract for their completion in April 1959. A further four were ordered on November 2, 1960.

Following tests and acceptance by the UK, the US and West Germany, on May 22, 1962, Hawker received a formal Instruction to Proceed with procurement of materials for nine further aircraft under the new designation Kestrel FGA.1.

At around the same time as the RAF's interest in the concept, NATO proceeded to develop its own specification, NBMR-3, which called for a VTOL aircraft to replace existing Fiat G.91 and Lockheed F-104G fighters.

The aircraft had to be able to deliver the same performance or equivalent to the conventional McDonnell Douglas F-4 Phantom II. In response, Hawker commenced work on developing a supersonic version of the P.1127/Kestrel, later designated P.1154. On December 6, 1961, prior to the design being submitted to NATO, it was decided that the P.1154 would be developed for both the RAF and the Royal Navy. When the design was submitted to NATO, it was chosen as the joint winner alongside the Dassault Mirage IIIV.

The (STOVL) F-35B is the replacement for the US Harrier AV-8B and the UK variants used by Royal Navy and RAF. **Picture USMC**

The UK has purchased the F-35B for its aircraft carriers, replacing the role of the older Harrier that was taken out of service officially in 2011, leaving a seven-year gap in the fleet. **Picture US DoD**

The F-35B is capable of deploying on operations alongside or in support of the F-22 Raptor. **Picture US DoD**

The Royal Navy has 34 F-35Bs in service currently with more expected to be delivered from the US by the end of 2025. **Picture US DoD**

When the initial NBMR-3 requirement petered out, Hawker Siddeley focused its attention on the British joint requirement for a VTOL platform. Accordingly, development of the type continued for some time. However, by October 1963 the Ministry of Aviation was concerned with the project's progress, and noted that the effort to combine a strike aircraft and a fighter in a single aircraft, and trying to fit that same airframe to the requirements of both services, was 'unsound'.

On February 2, 1965, work on the supersonic P.1154 was cancelled by the new British government on the grounds of cost. The then-Labour administration, under Prime Minister Harold Wilson, had instigated major cuts in a defence review, scaling back investment and development. Development continued on the subsonic P.1127/Kestrel evaluation aircraft and during 1964, the first of these commenced flight operations. Like the P.1127, the more advanced Kestrel was assessed by British, US and German pilots, to determine how VTOL aircraft could be employed, with the evaluations being finalised in November 1965. The Americans liked the Kestrel, but the German government did not invest. The full production model, now named Harrier GR.1 made its first flight on December 28, 1967, and entered service in April 1969.

The UK received 61 GR.1s, 17 new-build GR.1As with upgraded engines and 40 new-build GR.3s with further uprated engines and new sensors. The US Marine Corps received the export model, designated AV-8A Harrier, which was broadly similar to the RAF's GR.1 but with an engine similar to that of the GR.3. Differences in the American variant included the removal of all magnesium components, which quickly corroded in a naval operating environment, the installation of US radio systems and IFF, and outer wing pylons adapted to carry AIM-9 Sidewinder missiles. A total of 102 AV-8As and eight two-seater two-seater TAV-8A Harriers were delivered between 1971 and 1976.

During the early 1970s, the British and Americans worked together on a second-generation Harrier but the UK subsequently withdrew from the programme, leaving McDonnell Douglas to extensively redesign the AV-8A to create the AV-8B Harrier II – with a new and larger composite wing providing an additional hardpoint on either side. The fuselage was also redesigned, with structural and aerodynamic refinements, and the cockpit was elevated for improved visibility. The AV-8B made its first flight in 1981 and entered service with the USMC in January 1985. Later upgrades added a night-attack capability and an advanced radar variant, resulting in the AV-8B(NA) and AV-8B Harrier II Plus versions, respectively.

In parallel, the British had developed a navalised version of the GR.3, designated FRS.1 Sea Harrier, which entered service in 1978 – although it was only declared operational in 1981. This also had a raised cockpit and its fuselage was extended forward to accommodate the Ferranti Blue Fox radar system.

The collapse of the Soviet Union in 1991 was sudden and took Western governments by surprise. Defence planners, whose protocols and strategies had for decades been based on countering a Soviet opponent, were left uncertain as to who now presented the greatest threat – and when that threat would fully emerge.

The SVTOL role of the F-35 allows it to operate in support of the Marines and infantry and operate from forward operating bases on the land. **Picture USMC**

The USAF already had plans underway for a new fighter to replace the F-16 and other airframes but was left with little funding as a result of financing the development of the F-22 Raptor. In addition, the US Marines faced heavy criticism from the then-Vice President Dick Cheney about the growing cost of the new V-22 Osprey tiltrotor, which was suffering expensive delays resulting in a funding gap when it came to replacing the AV-8B Harrier. Consequently, although it took considerable time, the military were forced to work together on a joint 'tri-service' project which would eventually serve the Air Force, Navy and Marines.

Since the AV-8B's introduction, it has seen combat service in Operation Desert Storm, Operation Allied Force over the former Yugoslavia, Operation Enduring Freedom over Afghanistan, and Operation Iraqi Freedom. More recently the AV-8Bs have operated aboard US assault ships and mounted combat air patrols to deter Houthi attacks on commercial shipping in the Red Sea.

Finding a suitable replacement for the Harrier II was seen as fundamental in providing integral combat air support to the US Navy's amphibious operations.

USMC F-35B

While the F-35B's STOVL capability makes it a direct replacement for the Harrier, for the US Marine Corps it also replaces the McDonnell Douglas F/A-18. It had been intended at one point that it would also replace the Grumman EA-6B Prowler – retired in March 2019 – but that role was subsequently filled by the EA-18G Growler, a derivative of the F/A-18F Super Hornet.

Marine Fighter Attack Squadron 451 'Warlords' (VMFA-451), a unit deactivated in 1997, was reactivated at Naval Air Station Pensacola in April 2010 and redesignated Marine Fighter Attack Training Squadron 501 (VMFAT-501). It was to be based at Eglin AFB, Florida, and received its first F-35B in January 2012. The unit then formally commenced operations with the aircraft four months later.

VMFA-121 then became the first operational unit to receive the F-35B during ceremonies to mark the delivery of three new aircraft to Yuma on November 16, 2012. At the time, Lockheed Martin chairman and CEO Bob Stevens said: "For more than 50 years, it has been our mission to support the Marine Corps mission, and we're honoured to deliver the first three F-35B STOVL aircraft to Marine Fighter Attack Squadron 121. The F-35B is the world's only fifth generation, supersonic, stealthy combat aircraft that can also hover, take off and land virtually anywhere Marines are in action."

VMFAT-501 moved back to its permanent base at MCAS Beaufort in July 2014 and today continues to operate 27 F-35Bs as the Fleet Replacement Squadron.

At the time of writing, the USMC intended to keep its 179 F/A-18Cs and two-seater F/A-18Ds flying until 2030 or later due to delays in F-35B deliveries resulting from instability of the Technical Refresh-3 software which underpins the F-35B's Block 4 sensor, networking and weapons upgrades.

The last AV-8B Harrier IIs were due to retire from service in 2027.

MARINES
MARINES

The internal weapons bays allow the F-35B to carry an extensive payload although the F35A and C can carry more weapons. **Picture USMC**

RAF/Royal Navy F-35B

The UK had announced its intention to buy the F-35B in 2006. There had been debates about purchasing the F-35C as a catapult-launched asset, but in the end the decision was made to opt for the more expensive STOVL F-35B.

By June 2013, the UK had received three F-35Bs of the initial order for 48. Two years later, on June 19, 2015, the F-35B was launched from a ski-jump for the first time, with British BAE Systems test pilot Pete 'Wizzer' Wilson at the controls. This marked the beginning of a two-week initial testing phase at Naval Air Station Patuxent River in Maryland, USA.

Wilson said afterwards: "It's always exciting when you get to do something in aviation for the first time. We spend literally years planning these 'firsts', with hundreds of hours in the simulator as the event gets close, but even with all the preparation the test team remains focused on the potential that something unexpected might happen. As is usually the case, the jet performed as expected and it was a real pleasure."

While both RAF and Royal Navy pilots operate with the Joint Lightning Force, each service has its own squadrons. The RAF's famous 617 (Dambusters) Squadron was re-formed in August 2018 to become the UK's first F-35 unit.

On January 10, 2019, 617 Squadron and its F-35s were declared combat-ready and April 2019 saw the first overseas deployment of a UK F-35 squadron when 617 Squadron deployed to RAF Akrotiri in Cyprus. Then in June, the RAF reported its first combat patrol of an RAF F-35B when two aircraft took part in an armed reconnaissance flight, searching for Islamic State targets in Iraq and Syria. The following month it was announced that the RAF's 207 Squadron would become the second unit to be formed and would operate as the operational conversion unit for pilots moving to the F-35B.

617 Squadron embarked on the carrier HMS *Queen Elizabeth* to join Exercise Westlant 19, which saw the first deck landings of an F-35B on a UK carrier, in October 2019. Onboard, seven British jets were supplemented by four additional USMC F-35Bs, whose pilots were able to share valuable experience as the UK crews were put through their paces. The exercise saw the US pilots working with 617 Squadron to carry out combat air patrol procedures which were coordinated with fighter controllers onboard the *Queen Elizabeth* and her escort destroyer HMS *Dragon*.

In December 2023, the Royal Navy's 809 Naval Air Squadron, known as the Immortals, was re-formed to become the fleet's first F-35B formation. At the reformation ceremony, the last naval officer to command the unit, Commander Tim Gedge, symbolically presented the unit crest – a phoenix rising from the flames – to the pilot in charge of its rebirth, Commander Nick Smith. Cdr Smith said: "The squadron has a rich history of Royal Navy and Royal Air Force integration, from the days of operating the Blackburn Buccaneer at RAF Lossiemouth in the 1960s and 1970s to the Falklands Conflict in 1982, and this is set to endure well into the future."

Also at the event, Vice Admiral Connell, then the Second Sea Lord said: "The Lightning is two generations ahead of the Sea Harrier Commander Gedge and his colleagues flew in the Falklands, in 809's most recent iteration – although both aircraft are equally at home operating on land or from the decks of Royal Navy aircraft carriers. And though a naval air squadron, 809 – like 617 Squadron before it – is a national asset, its personnel drawn from both the RAF and Royal Navy, its commanding officer alternating between the two Services."

The UK currently has 41 F-35B stealth jets in service, with 38 in the Lightning Force and three in the US for testing, with RAF Marham overseeing UK F-35B operations. The UK's fleet of F-35Bs is expected, on current planning, to grow to 74 aircraft by 2033, although there has been discussion about the UK procuring the F-35A.

▶

As of 2025 the F-35B is the main aircraft for supporting the Marines with the Harrier AV-8B officially being retired by early 2026. This VMFA-242 'Bats' aircraft displays an appropriate logo on the underside of its lift fan door. **Picture USMC**

Made in Italy

Italy is host to the only F-35 manufacturing facility outside the United States. The Italian Final Assembly and Check Out (FACO) facility at Cameri is owned by the Italian Ministry of Defence and operated by defence contractor Leonardo in conjunction with Lockheed Martin, with a workforce of more than 800 skilled personnel engaged in full assembly of the F-35A and F-35B as well as F-35A wing production.

The factory commenced operations in July 2013 and the first Italian-assembled F-35A was rolled out on March 16, 2015 followed by the facility's first F-35B on May 5, 2017.

As of July 2024, the Italian Air Force had received 24 F-35As and two F-35Bs. It is planned that the Air Force will operate a total of 75 F-35As and 20 F-35Bs, while the Italian Navy's Carrier Air Group will have a total of 20 F-35Bs.

First combat operations

After the initial declaration of IOC in 2015, the Marine Corps' F-35Bs participated in their first major exercise in July 2016. A year later, VMFA-121 and its F-35Bs were deployed to MCAS Iwaki in Japan.

In September 2018, F-35Bs from a second unit, VMFA-211, based at MCAS Yuma in Arizona, became the first squadron with the new fighter to deploy to the US Central Command area of operations. They were based aboard the Wasp-class amphibious assault ship USS *Essex* in support of the 13th Marine Expeditionary Unit (13th MEU). On September 27, two of the F-35s deployed forward with the 13th MEU and mounted the first combat mission for the F-35B variant when they engaged a 'fixed' Taliban target, believed to be a bomb making factory near Kandahar in Afghanistan.

It is understood that this first air strike used a GBU-32 1,000lb JDAM carried under the weapons bay. At the time the USS *Essex* was positioned in the North Arabian Sea and the operation also recorded what was then the longest-range airstrike launched from the Wasp-class. At the time, Colonel Chandler Nelms, commanding officer of the 13th MEU said: "The opportunity for us to be the first Navy, Marine Corps team to employ the F-35B in support of manoeuvre forces on the ground, demonstrates one aspect of the capabilities this platform brings to the region, our allies, and our partners."

In 2021, F-35B jets from the RAF's 617 (Dambusters) Squadron mounted their first operational combat strikes against Islamic State on the border of Northern Iraq and Syria. The aircraft had launched from the aircraft carrier HMS *Queen*

Elizabeth, flagship of the UK's Carrier Strike Group (CSG) and deployed in support of the UK's Operation Shader and the US mission in the region, codenamed Operation Inherent Resolve.

At the time of the operation, the Royal Navy carrier had 18 UK and US F-35B jets on board. The mission was historic as it was the first time US aircraft had launched combat missions from a foreign carrier since US warplanes served aboard the carrier HMS *Victorious* in the South Pacific in 1943. At the time, UK Defence Secretary Ben Wallace said: "The ability to operate from the sea with the most advanced fighter jets ever created is a significant moment in our history, offering reassurance to our allies and demonstrating the UK's formidable air power to our adversaries.

"The Carrier Strike Group is a physical embodiment of global Britain and a show of international military strength that will deter anyone who seeks to undermine global security."

In November 2021, Italy – which took delivery of its first F-35B in 2018 – made its first landing on the *Cavour,* Italy's aircraft carrier. More recently Italy supported NATO's Interim Air Policing Mission, deploying F-35Bs to Iceland where Alliance forces mount ongoing patrols to deter Russian incursions into the region.

In May 2025, the UK deployed its second carrier, HMS *Prince of Wales,* with 18 F-35Bs to the Indo-Pacific. A further six aircraft were due to be added to the ship's complement later, bringing the total up to full squadron strength.

Losses

To date, the US military has lost 13 F-35s in aviation accidents; the most recent took place in January 2025 when an F-35A crashed at Eielson Air Force base, 20 miles south of Fairbanks in Alaska. The pilot was able to eject but did sustain injuries. The UK has recorded one incident, which took place in November 2021 when an F-35B ditched into the eastern Mediterranean as it lifted off from HMS *Queen Elizabeth* during a deployment codenamed *Operation Fortis*.

The basic cause of the accident was understood very quickly, but the full board of enquiry report highlights multiple contributing factors and reveals broader issues with UK Carrier Strike capability. The F-35B aircraft, ZM152, also known by its construction number BK-18 and flown by a Royal Navy pilot, was attempting to take off from the carrier on a training sortie.

EG
MARINES
NJ
NAVY

The F-35 comes in three variants, the A,B and C all with different purposes. The B is most suited to amphibious assault operations. **Picture USMC**

First line shelters, such as the one in this picture, are used to park aircraft when they are at readiness, or for quick routine maintenance. **Picture USMC**

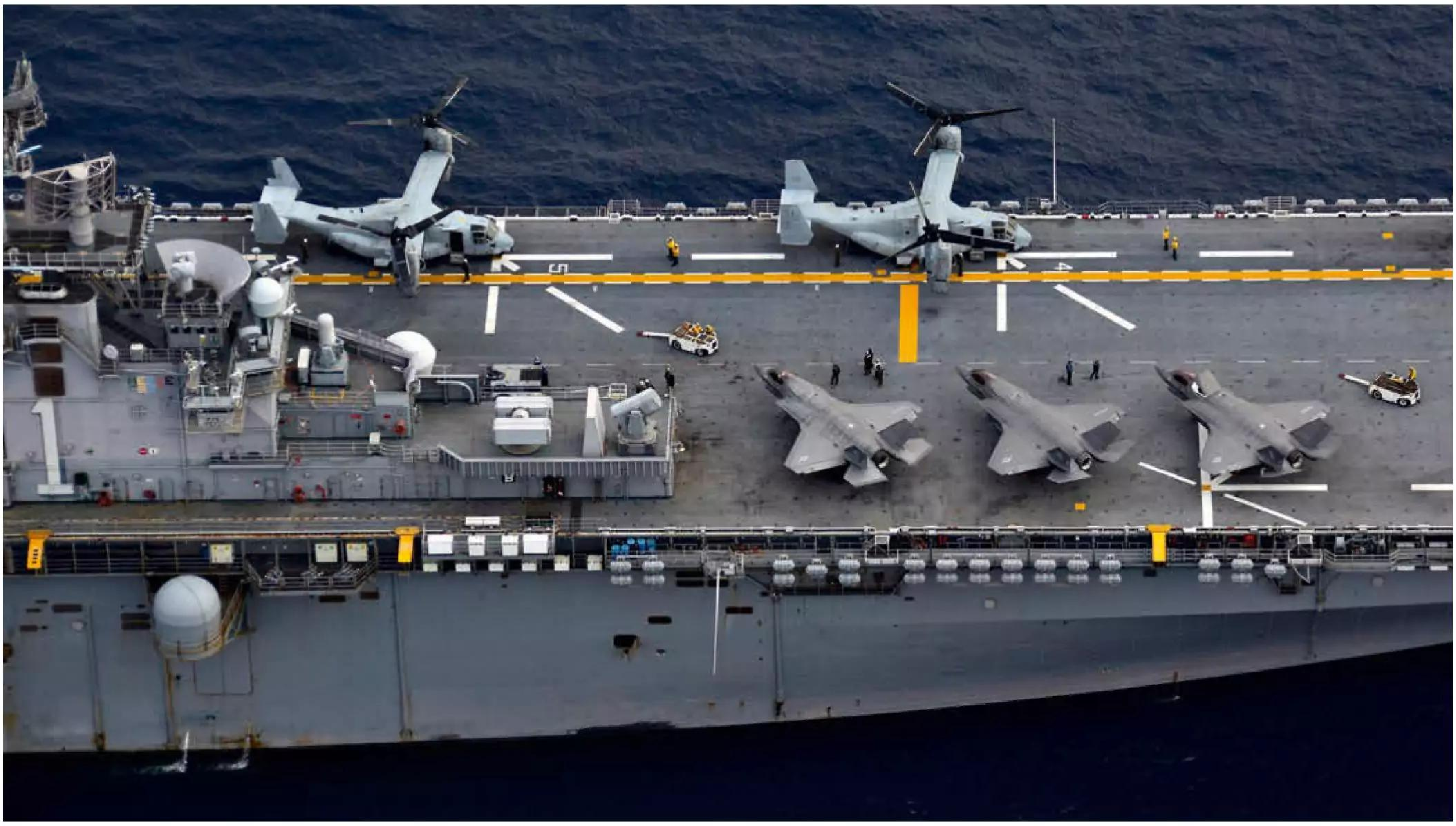
A USMC F-35B lands on the UK carrier HMS *Queen Elizabeth*. **Picture USMC**

A British RAF Harrier. These aircraft, the pioneers of vertical take-off and landing, were used widely on operations from the Falklands to Iraq and Afghanistan. **Picture DPL**

US Marines Harrier AV-8Bs pictured during an air-to-air refuelling. The AV-8B had a long career with operational deployments in the Balkans, Iraq and Afghanistan. **Picture USMC**

The last operational mission for the Harrier AV-8B took place over Syria. **Picture USMC**

F-35B landing on an assault ship after a mission in support of US Marines. **Picture USMC**



F-35Bs parked alongside Osprey V-22s on the flight deck of an assault ship. During operations the F-35Bs are tasked to provide protection for the V-22s. **Picture USMC.**

US F-35B pictured during low-level training manoeuvres in northern England.

The UK is scheduled to buy more F-35Bs and has indicated that it will also purchase a dozen F-35As capable of dropping nuclear bombs. **Picture USMC**

VMFA-12
DANGER-FAN INTAKE-DANGER
JET INTAKE DANGER
DANGER
RESCUE
01
Aircraft engineers check an F-35B during initial trials aboard a US carrier. **Picture US Navy**

F-35B was selected by the UK to replace the Harrier and avoid fitting the arrestor and catapults required to launch the F-35C. **Picture USMC**

However, due to a protective engine blank being accidently left in the intake duct, the engine was only able to generate 55% of the thrust needed for the aircraft to take off from the ski ramp. Realising something was amiss, the pilot attempted to abort but it was too late and the jet was about to fall off the ramp when he was forced to eject. Following the successful ejection, the pilot descended by parachute, fortunately landing on the flight deck and avoiding the extreme hazard of landing in the water and being run over by the ship. He suffered cuts to his neck and other minor injuries but was not seriously hurt. The aircraft was seen to be afloat as the ship passed by but sank shortly afterwards.

The report identified a series of small issues that contributed to the accident. Some are part of a systemic force-generation problem, while others might be seen as typical lessons learned through experience with new jets on a new carrier conducting its first long deployment. A key misstep was the way that 'red gear' items used to protect the aircraft were handled by engineers.

These 'red gear' items usually protect vital parts of the aircraft such as engine intakes that are covered when the aircraft is stored and are marked with a red flag. The naval inquiry found that storage solution and logging methods for recording the issue or return of red gear was weak, and there was no system in place that would immediately make it obvious that one item must still be on an aircraft due to fly. The risks from Foreign Object Damage (FOD) from litter on the flight deck, such as screws, bolts and wire which can be sucked into an engine, were always treated very seriously, but red gear was regarded more as a risk to other aircraft rather than the aircraft it was fitted to.

This is despite the fact that four instances of red gear being sucked into F-35 engines had been recorded by US operators, although none had resulted in the loss of an aircraft. The design of the red gear for the F-35 had gone through various iterations but was found to be unsatisfactory. Ironically, the text 'Remove before flight' was printed on the intake blanks by the manufacturer but the characters were found to peel off and presented a FOD hazard. As a result, 617 Squadron engineers had removed the lettering. Furthermore, a pop-pin used to secure the intake cover in place was not always used, and there were numerous instances of red gear being blown off aircraft on the flight deck before a flight check – including on the day of the accident – and several had been lost overboard. ■

• F-35B Lightning II

Function: Multirole fighter
Prime contractor: Lockheed Martin
Crew: One
Power plant: 1 x Pratt & Whitney F135-PW-600 turbofan engine
Thrust: 38,000lb/40,500lb vertical (less than the F-35A)
Wingspan: 35ft
Length: 51.2ft
Height: 14ft
Internal fuel capacity: 13,100lb (less than the F-35A)
Payload: 15,000lb (less than the F-35A)
Speed: Mach 1.6 (1,200mph)
Range: More than 900 nautical miles on internal fuel (less than the F-35A)
Ceiling: Above 50,000ft
Armament: Internal and external capability. Munitions carried vary based on mission requirements

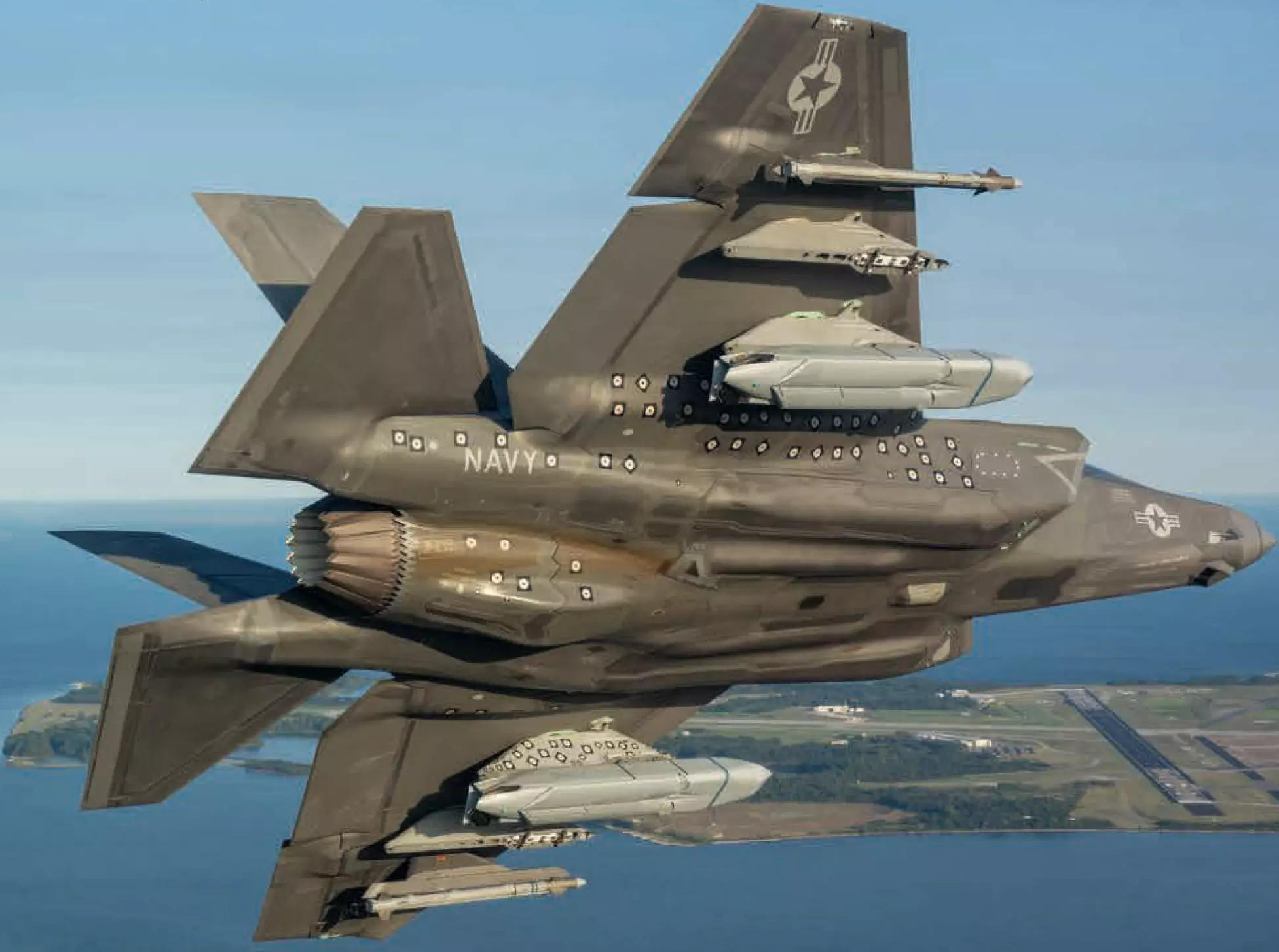
4

CHAPTER

The F-35C Variant

Designed and built explicitly for the US Navy's carrier operations, the long-range F-35C's only other operator is the US Marine Corps. On the flight deck it serves alongside the fleet's upgraded F/A 18E/F Super Hornets and has taken part in recent operations against Houthi rebels in Yemen. The C's wings are larger than those on the A and B variants and can be folded to make parking on the flight deck easier. The C also has heavier and more robust landing gear with a twin-wheel nose gear and an arrestor hook, as well as additional fuel capacity.

F-35C graced the skies for the first time on June 6, 2010, and the Pentagon has plans to procure more than 270 for the US Navy. Initially, the USMC only procured a small number of Cs to operate alongside the STOVL F-35B but it has since opted to buy more and under current plans the service will acquire 67 of the variant.



An F-35C flies in 'beast mode' during certification to carry the AGM-158C Long-Range Anti-Ship Missile (LRASM) and other weapons.
Picture US Navy

Big-wing F-35

The F-35C was intended from the beginning to replace the US Navy's F/A-18 Hornets and A-6 Intruders, operating alongside the F/A-18E/F Super Hornet. The type's critical design review was completed in June 2007 and the first example was rolled out from Lockheed Martin's Fort Worth Facility in July 2009.

Unlike the other F-35 variants, the F-35C was required to undergo a programme of full-scale drop tests to verify the strength of its landing gear and airframe structure for carrier landing operations. Vought Aircraft Industries had taken possession of CG-1, an F-35 ground test airframe, by November 2009 and proceeded to fit it with drop test fixtures, test systems and instrumentation at the company's Dallas facility.

The actual drop testing – simulating 47 shipboard landings for a variety of design touchdown conditions at specified aircraft altitudes, sink rates and stores configurations – then commenced in January 2010 and continued into April of that year. For example, on March 27, CG-1 was dropped from a height of nearly 8ft off the ground at a rate of 20ft per second, with an 8.8-degree pitch, 2-degree roll and 133-knot wheel speed.

The first F-35C flight test airframe, CF-1, made its first taxi run on May 28, 2010, in unpainted condition, before Lockheed Martin test pilot Jeff Knowles took it up into the air for the first time on June 6 of that year.

The first production model F-35C, CF-6, made its maiden flight from Fort Worth on February 14, 2013, and the US Navy's first F-35C delivery was made to Strike Fighter Squadron 101 (VFA-101) in June 24, 2013. VFA-101 serves as the F-35C Fleet Replacement Squadron, training aircrew to fly it and maintenance personnel to repair it.

The Marine Corps received its first F-35C on January 21, 2020, with the aircraft being received by VMFA-314 – the 'Black Knights' – at Miramar in San Diego, California. The unit reached IOC on December 1, 2020, and was declared fully operation in July 2021.

F-35 tailhook

It goes without saying that the F-35C, the dedicated carrier variant, is the only one fitted with a tailhook. Early trials with the first tailhook designed for the F-35C took place in the summer of 2011 and proved to be a failure. During tests conducted at Naval Air

An F-35C of Air Test and Evaluation Squadron (VX) 23 prepares for take-off aboard the aircraft carrier USS *Dwight D. Eisenhower*. **Picture US Navy**

The arrestor wire on the deck of the USS *Nimitz* catches the tailhook to brake an F-35C as it lands on deck. **Picture US Navy**

Warfare Center – Aircraft Division at Lakehurst, New Jersey, the F-35C failed to engage the Mk-7 arresting gear with a disappointing score of zero successes out of eight attempts.

Subsequent reports blamed arresting hook system design issues and aircraft geometry, specifically the short distance between the main landing gear tyres and the tailhook point. In other words, the 7.1ft distance between the tyres and the tailhook was too short, resulting in the cable still being virtually flat against the deck by the time the tailhook arrived ready to intercept it.

Evidently the hook itself kept rebounding at very high angular accelerations, damaging the test team's fragile tailhook instrumentation.

The original F-35C tailhook design had been based on that of the F/A-18 Hornet, but the distance between the main gear tyres and the tailhook on that aircraft is 18.2ft – a much greater distance which gives the 'trampled' cable enough time to respond and flex back into its original position.

The tailhook assembly was subsequently redesigned and US Navy test pilot Cmdr. Tony 'Brick' Wilson, flying F-35C CF-3, was finally able to make a successful arrested landing on the deck of the USS *Nimitz* on November 3, 2014. During the tests that followed, two F-35Cs managed to accomplish 124 catapults and arrestments plus 222 touch-and-go landings and a range of other deck operations without issue.

The new hook features a much stronger hold down damper, an all-new damper for the upstroke, a better lateral limiter and improved instrumentation – plus a new hook shoe.

The F-35C's hook is stowed in a bay at the rear that is covered by clamshell doors during flight. It is electronically controlled and moved by hydraulics.

Probe-and-drogue

While the F-35A is configured for the flying boom method of air-to-air refuelling, the F-35B and F-35C use the probe-and-drogue method. With flying boom, an operator aboard the tanker works with both the tanker and receiving aircraft pilots to guide each aircraft into the correct position. They

then use 'ruddervators' to manoeuvre an extendable tube – the flying boom – into the receiving aircraft's receptacle. This is on the F-35A's back.

With probe-and-drogue, the tanker flies straight and level while extending a hose with a drogue or 'basket' on the end from the rear. This is allowed to trail out freely behind and below the aircraft. The pilot of the receiving aircraft then extends a probe, usually mounted on the aircraft's nose, and manoeuvres their aircraft until the probe connects and locks into the drogue basket. The fuel transfer can then begin.

The flying boom is easier for the pilot, generally safer and has a much high rate of fuel transfer but it also requires the tanker aircraft to be fitted with a large piece of dedicated equipment. The F-35A could be fitted with a probe but this would need to be done at the factory prior to delivery.

The probe-and-drogue method is used by the US Navy, USMC and most other nations around the world. It is much more compact and can be carried out by most tactical and transport aircraft simply by fitting them with external fuel tanks to serve as tankers. The US Navy can therefore use a buddy refuelling system, with F/A-18E/Fs carrying external tanks and refuelling F-35Cs from them.

As such the F-35C, like the F-35B, features a retractable 5.5ft long aluminium alloy refuelling probe on the right side of the front fuselage.

Weapons payload

The F-35C can carry the same weapons payload as the F-35A – either 5,000lb of internal weapons, or more than 18,000lb of combined internal and external weapons. This allows the Navy to operate in stealth when necessary or increase lethality with additional weapons externally when stealth is not an issue.

Unlike the F-35A, however, it lacks an internal 25mm Gatling-type gun. If one is required, it can be fitted with a single belly-mounted missionised gun system pod housing both the gun itself, a four-barrel GAU-22/A cannon, and 220 rounds of ammunition. The F-35B also lacks an internal gun and needs a gun pod – but due to the F-35C's different external mould line the pods are not interchangeable and each requires its own bespoke unit.

For air-to-air engagements the F-35C counts on the Raytheon AIM-120C AMRAAM missile, the only medium-range missile currently integrated

F-35C pictured at a naval shore base during development testing. **Picture US DoD**

F-35C lands on the deck of the USS *George Washington*. **Picture US Navy**

F-35C gets airborne off the deck of the USS *George Washington*. **Picture US Navy**

with the F-35. The aircraft can carry up to four of these in its internal bays in stealth mode. The second air-to-air missile is the AIM-9X Block II short-range missile, which can be carried on the outer underwing pylons and is the most-used missile on F-35s in foreign service (although the UK uses the AIM-132 ASRAAM instead, as well the MBDA Meteor as of 2025).

The standard air-to-ground weapons for the F-35C are the 2,000lb GBU-31 JDAM, 1,000lb GBU-32 JDAM and GBU-12 Paveway II. As of March 2024, the USAF's F-35A was operationally certified to carry the B61-12 thermonuclear gravity bomb – but although the Navy's F-35C could theoretically accommodate the B61 it is not currently certified to do so.

Operationally ready

The Navy's first operational F-35C squadron, VFA-147 'Argonauts', based at Naval Air Station Lemoore in California, deployed aboard the carrier USS *Carl Vinson* in late 2018 and received its safe-for-flight operations certification six months later. Pilots were required to undergo a range of trials, from deck refuelling to night vision flying and what the fleet calls 'bumps and lifts', in which pilots land and then take-off straight away. On February 28, 2019, the US Navy declared initial operational capability of the F-35C.

VFA-147 was declared operational in August 2021 and deployed to the Indo-Pacific region as part of the carrier air wing aboard the *Carl Vinson*. Initially, the US Navy had three primary F-35C squadrons with VFA-147 'Argonauts' based at Iwakuni in Japan plus VFA-97

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STRIKE TEST
NAVY
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An F-35C takes flight following a catapult launch. **Picture US Navy**

'Warhawks' and VFA-86 'Sidewinders' both based at Lemoore. A training and replacement squadron, VFA-125 'Rough Riders', was formed to generate new crews and adopt new flying principles. Additional F-35C squadrons are expected to be formed as part of the Navy's planned acquisition of 273 F-35Cs, according to Lockheed Martin.

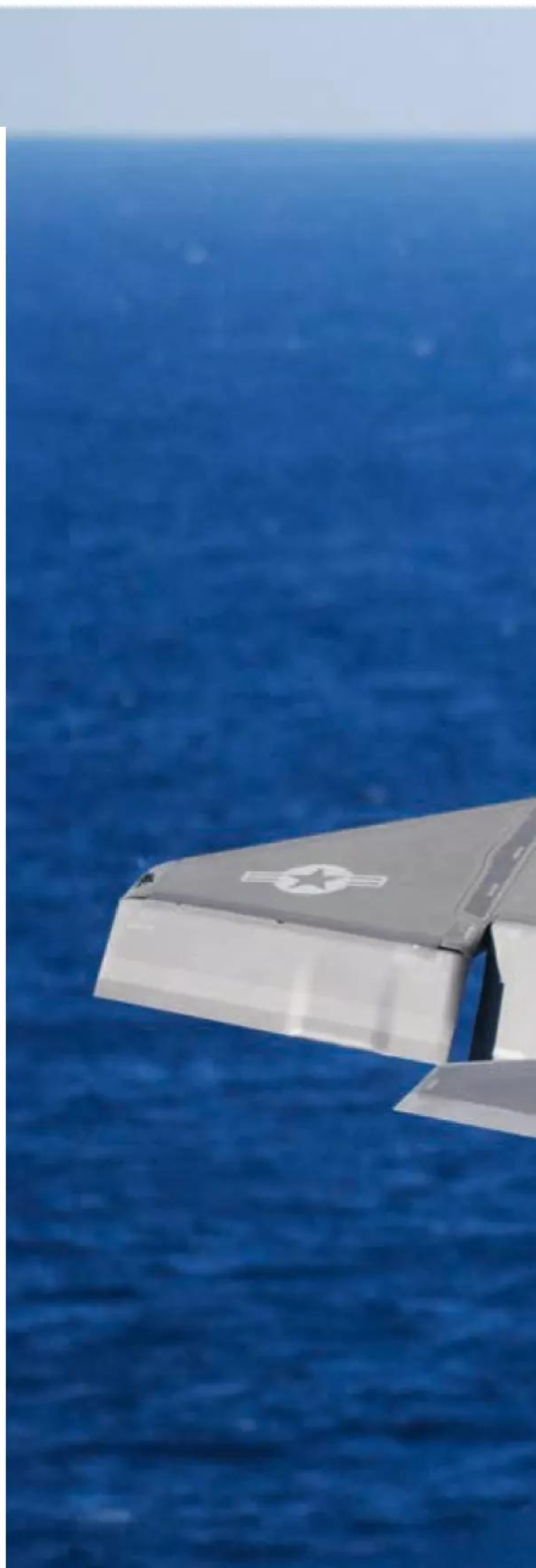
The USMC has three F-35C squadrons: VMFA-314 and VMFA-311 'Tomcats', both located at Miramar, and VFMA-251 'Thunderbolts' at Cherry Point in North Carolina. VMFA-311 achieved IOC in July 2024. The Marines plan to have a total of eight F-35C squadrons and are increasing their acquisition of F-35Cs, while scaling back on the F-35B STOVL variant. The US Marine Corps' latest Aviation Plan for 2025 proposes more than doubling of the number of F-35Cs from 67 to 140. To compensate, the Corps has reduced its planned acquisition of F-35Bs from 353 to 280.

The US Marine Corps currently possesses 183 F-35B and 52 F-35C aircraft across two fleet replacement squadron detachments, operational test squadrons and 11 fleet squadrons. The planned number of 420 F-35s operated by the USMC remains unchanged, but the breakdown of F-35B and F-35C will see eight squadrons of F-35Cs operating 12 aircraft each.

The F-35C is currently only able to operate from four of the Navy's 11 aircraft carriers: the *Carl Vinson* (CVN-70), USS *Abraham Lincoln* (CVN-72), USS *George Washington* (CVN-73), and the USS *Theodore Roosevelt* (CNV-71). In order to accommodate the F-35C, ▶

F-35C pictured during night operations – the pilot's advanced helmet has a built-in night vision system. **Picture US Navy**

F-35C taxis away from the main runway after landing on the USS *Abraham Lincoln*, **Picture US Navy**



carrier maintenance spaces need to be reconfigured, weapons lockers need to be altered to suit F-35-specific weapons, crews need to be retrained and additional heat protection needs to be applied in some areas.

Most of the seven aircraft carriers currently unable to take the F-35C will eventually be upgraded to operate it as they pass through their maintenance and upgrade cycles.

One or two of the remaining carriers are not likely to be certified to operate the F-35C – the USS *Nimitz* (CNV-68) is expected to begin its retirement in 2025 and the USS *Dwight D. Eisenhower* (CVN-69) is also expected to retire by around 2029. Ironically, the Navy's newest aircraft carrier, the USS *Gerald R. Ford* (CVN-78) will be the last carrier to be certified. Future carriers, starting with the USS *John F. Kennedy* (CVN-79) will be commissioned ready to operate F-35Cs as standard.

In addition, the Navy has nine amphibious assault ships – the Wasp class and the American class – from

STRIKE TEST
NAVY
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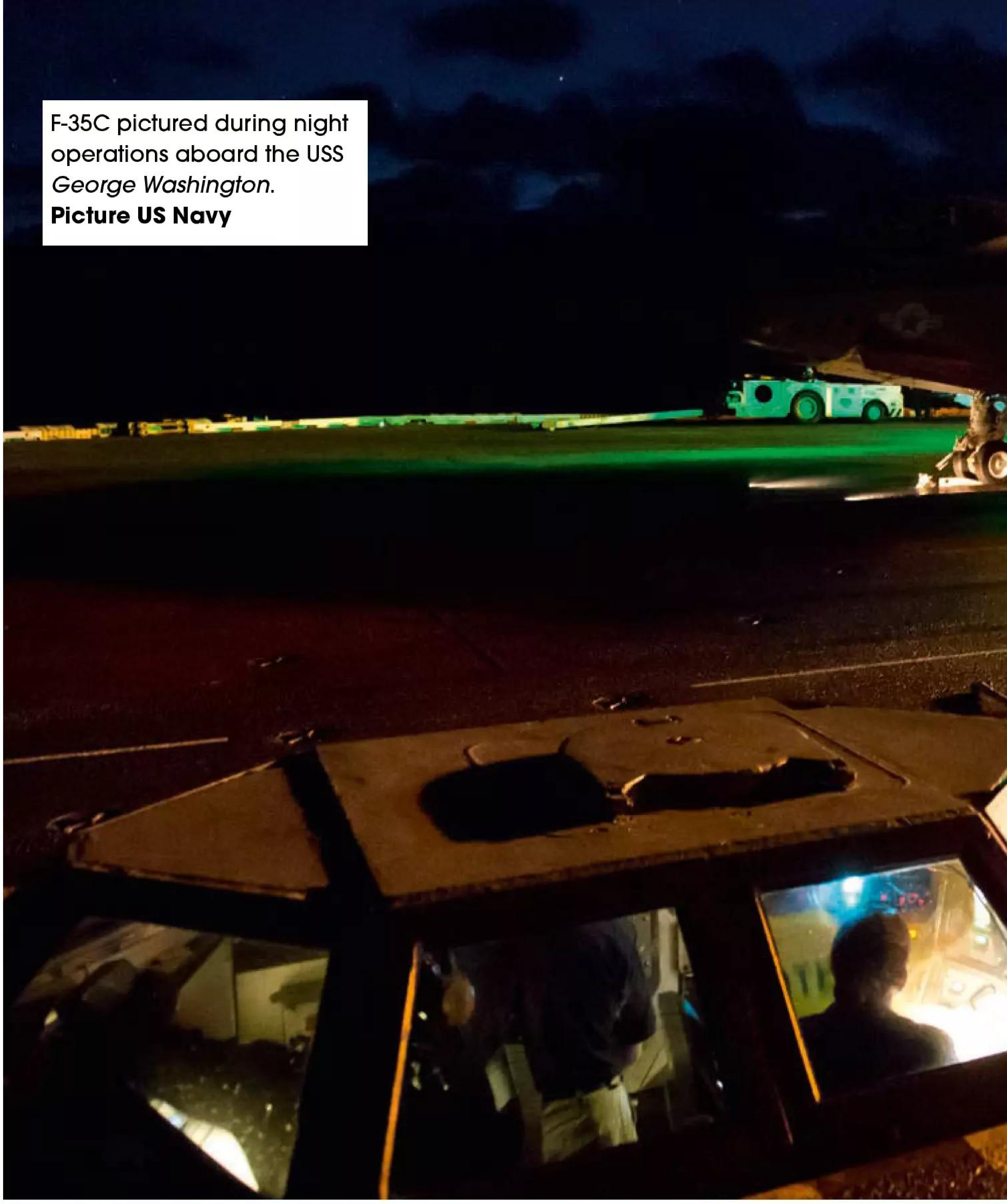
US Navy F-35C lifts off from the deck of USS *Abraham Lincoln*.

which the US Marine Corps operates. These too have been or will be modified to operate F-35s, albeit the F-35B rather than the F-35C. Those upgraded at the time of writing were the USS *Wasp* and USS *America* themselves, the USS *Essex*, USS *Makin Island* and USS *Boxer*.

Combat operations

US Navy F-35Cs mounted their first combat mission on November 14, 2024, when they intercepted numerous drones and missiles fired by Houthi rebels at US warships transiting the Red Sea. The attack, involving eight drones, five anti-ship ballistic missiles and three cruise missiles, was directed at the Arleigh Burke class guided missile destroyers *USS Stockdale* and *USS Spruance,* both port-based at San Diego, California. The F-35Cs, based aboard the *Carl Vinson,* were able to intercept and eliminate the threats. At the time, US Air Force Major General Pat Ryder stated that both missiles and drones were shot down by US defences.

The confrontation occurred after US Navy aircraft targeted several Houthi weapons storage sites in Yemen, which the Pentagon described as facilities containing 'advanced conventional weapons' used to threaten military and civilian ships in the region. The



F-35C pictured during night operations aboard the USS *George Washington*. **Picture US Navy**

US Navy F-35C aboard the aircraft carrier USS *Carl Vinson*. **Picture US Navy**

Pentagon official added: "Among the aircraft deployed in the recent operations were F-35Cs, marking what is the first combat mission carried out by an F-35C."

Four days later, on November 20, 2024, three USMC F-35Cs from VMFA-314, aboard *Abraham Lincoln*, conducted multiple strikes on Houthi weapons storage facilities in Yemen that housed conventional weapons, including anti-ship missiles. The Iranian-backed Houthis used these weapons to target US and international military and civilian vessels navigating international waters in the Red Sea and Gulf of Aden.

VMFA-314 commanding officer Lt. Col. Jeffrey 'Wiki' Davis said: "The F-35C demonstrated its warfighting advantage by transiting contested airspace and striking targets in the heart of Houthi territory over multiple days."

The 'chrome' F-35s

In January 2022 aviation photographer Elijah Delgadillo captured images of an F-35C belonging to experimental squadron VX-9 sporting a mysterious mirror-like surface coating similar to that first seen on a USAF F-22 in November 2021. Just days prior to the F-35C sighting, a USAF F-117 had also been seen wearing a similar reflective scheme.

F-35C serial number 169424 operating with VFA-86 as NG-302 in early 2025. **Picture US Navy**

F-35C waits in the deck of the USS *George Washington* for its turn to get airborne. **Picture US Navy**

An F-35C lands on the deck of the aircraft carrier USS *Dwight D. Eisenhower*, the arrestor wire clearly visible. **Picture US Navy**

DANGER
DANGER INTAKE
VX-23

F-35C test airframe #75 aboard USS *Abraham Lincoln*. **Picture US Navy**

Then in December 2023 images emerged showing an F-35C aircraft belonging to VFA-125 with its tail fins covered in the mirror surfacing. It had been photographed the previous month while undergoing trials aboard USS *Abraham Lincoln* off the California coast.

Depending on the viewing angle, it was noted that the coating changed significantly from opaque to transparent and from dark to shiny. It also appeared to be made from three different materials. It was theorised at the time that three different types of coating had been applied to the same aircraft for comparative purposes.

Further photos appeared in August 2024, with coated F-35C's operated by experimental unit VX-9 spotted at Edwards AFB and then in early 2025, photos appeared online showing a 'chrome' F-35C parked up at Midland airport, Texas, in November 2022. This time it was apparent that the coating was in the form of tiles, some of which were visibly degraded or corroded. Apparently, the pilot had told the photographer that the tiles "were to help with the salty air on the skin, but the [they] kept peeling off in flight".

Finally, in April 2025, the US Navy itself unveiled images of two F-35Cs equipped with the mirror coating during testing at Naval Base Ventura County Point Mugu in August 2022.

There have been many theories about the origin and purpose of the coatings but no official explanation has been given. The most popular theories hold that the coating is either counter IRST – InfraRed Search & Track – technology, some form of radar absorbent material replacement or even a passive laser defence system.

The name game

The F-35's official name is, of course, Lightning II – which pays homage to the famous Lockheed P-38 Lightning of the Second World War. However, the aircraft has been given various nicknames over the years as well.

Early on, some rather unflatteringly called the F-35A and B 'Fat Amy' with the F-35C being labelled 'Obese Amelia', based on the comparison between svelte legacy types such as the F-16 and F/A-18, which lack an internal weapons bay, and the stealth strike fighter which appears physically more dense owing to its much higher internal volume.

Subsequently, with the F-35A in service and with the world having become much more familiar with its looks, the USAF F-35A started to attract a much more pleasing monicker, particularly from the pilots who fly it: Panther.

Another more confusing nickname has also emerged, which seems to have been applied particularly to the F-35C: Battle Penguin. This evidently refers to the aircraft's broad fuselage and correspondingly stubby wings.

Why choose the F-35A?

Given that the F-35C has a greater fuel load and better range, with the same weapons payload and the same top speed – and is still reportedly cheaper than the F-35B – it might not seem immediately obvious why so many international F-35 customers have chosen to purchase the F-35A rather than the F-35C.

There is no single clear answer to this question but it can be said that the F-35A's built-in cannon is a distinct point of difference between the two aircraft and the F-35C has specifically naval features such as additional airframe and gear strengthening, folding wings and that tailhook which add weight and which many customer countries simply do not need.

F-35C lands on USS *Dwight D. Eisenhower*. **Picture US Navy**

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STRIKE TEST
VX-23
AFFF 9B

F-35C pilot waits on the deck of an aircraft carrier for clearance to take off. **Picture US Navy**

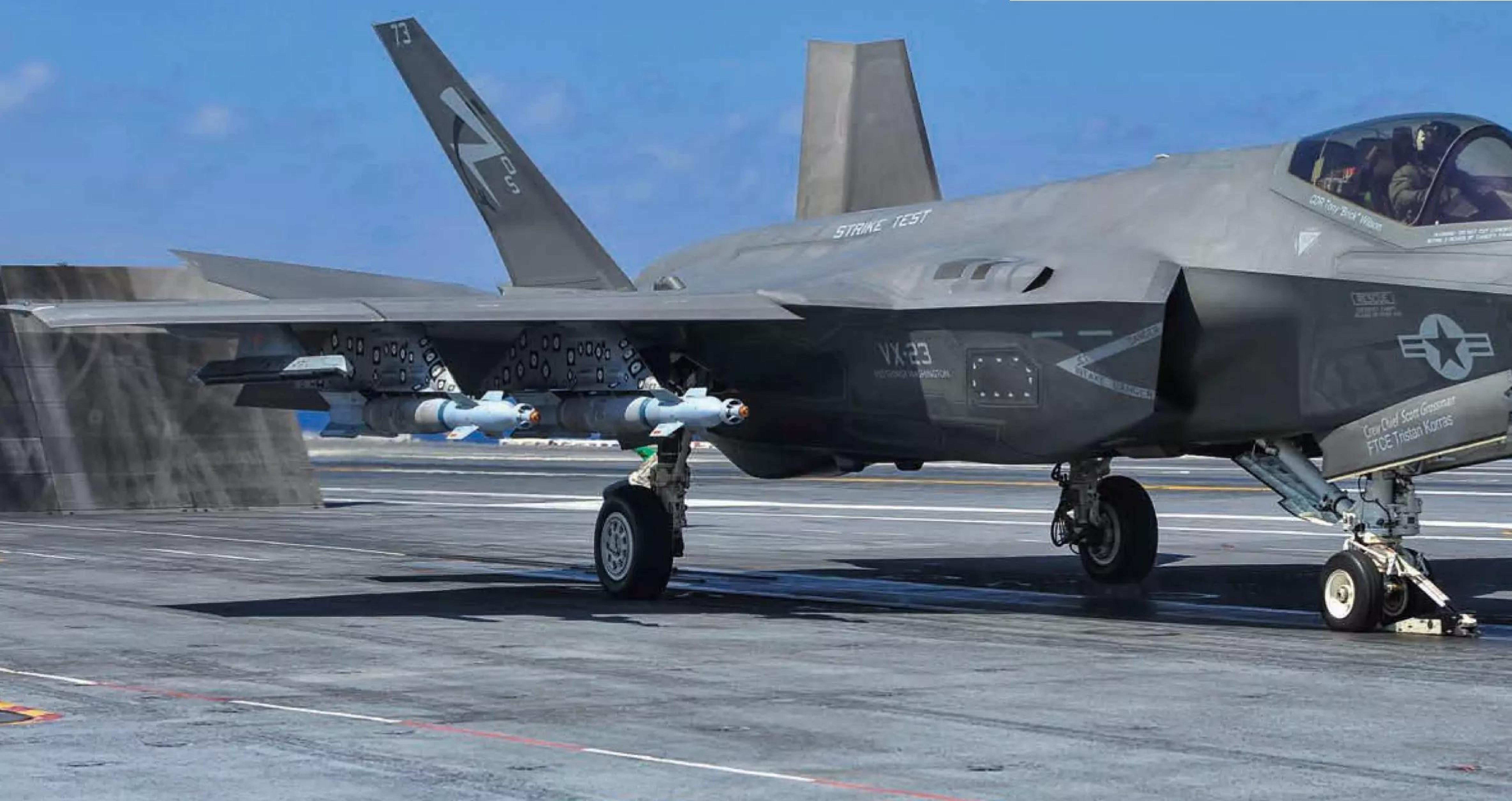
F-35C with a test and evaluation unit waits for word to be released by the USS *Dwight D. Eisenhower's* catapult system. **Picture US Navy**

As of May 2025, four Nimitz-class aircraft carriers, USS *Carl Vinson*, USS *Abraham Lincoln*, USS *George Washington*, and USS *Theodore Roosevelt*, have been upgraded to support operational deployments of the F-35. **Picture US Navy**

F-35C gets airborne from an aircraft carrier and appears to drop before lifting away. **Picture US Navy**

Another view of F-35 test airframe #73 with VX-23. **Picture US Navy**

F-35C test airframe with Paveway II bombs carried externally for tests. **Picture Royal Navy**


73
STRIKE TEST
VX-23
Crew Chief Scott Grossman
FTCE Tristan Korras

73
STRIKE TEST
VX-23
I K E

Another point of comparison might be found in the max G-rating of each variant. The F-35A's rating is 9.0, compared to the F-35B's 7.0 and the F-35C's 7.5. This means that, in common with other land-based fighters such as the F-16, the F-35A can withstand greater G-forces than the other two, allowing it to manoeuvre harder.

Additionally, naval aircraft have traditionally tended to feature a twin-engine design for safety while flying for long distances over open ocean and a second crewman to assist with navigation and weapons management. The F-35C, with its single engine and lone pilot, might therefore seem less attractive to potential naval customers.

Perhaps the greatest disincentive for those considering the F-35C is the additional operating cost as compared with the simpler F-35A. The F-35C's extra systems make it a somewhat more expensive aircraft to run and maintain day-to-day. ■

• F-35C Lightning II

Function: Multirole fighter
Prime contractor: Lockheed Martin
Crew: One
Power plant: 1 x Pratt & Whitney F135-PW-100 turbofan engine
Thrust: 40,000lb vertical
Wingspan: 43ft
Wing area: 668sq ft
Length: 51.5ft
Height: 14ft
Internal fuel capacity: 19,200lb
Payload: 18,000lb
Speed: Mach 1.6 (1,200mph)
Range: More than 1,200 nautical miles on internal fuel
Ceiling: Above 50,000ft
Armament: Internal and external capability. Munitions carried vary based on mission requirements

5
CHAPTER

The F-35I Adir – The Israeli Variant

Israel's F-35 variant was the first to see combat operations – in 2018 against Islamic State in Syria and targets of Iran's Islamic Revolutionary Guard Corps. More recently it was deployed in the war in Gaza and Lebanon and also in Yemen. The unique nature of the F-35I Adir is derived from a special agreement with Washington which secured major concessions for the Israelis to fit their own indigenous systems to the airframe. In fact, the Israeli Air Force (IAF) is the only nation outside of the United States allowed to make major modifications to the F-35. These changes include the fitting of an Israeli command and communications system, electronic warfare countermeasures and the authority to carry a range of non-US weapons, including the 1,000lb bomb known as the 'Smart, Precise, Impact, Cost Effective' or SPICE munition.

Israel procured the F-35 to replace its ageing fleet of F-16s, which have been in service for several decades. **Picture IAF**

The first experimental F-35A Adir arrived in June 2016. **Picture IAF**

The enhanced Israeli F-35I Adir replaces the role of the F-16 and more with its multi-role ability. **Picture IAF**

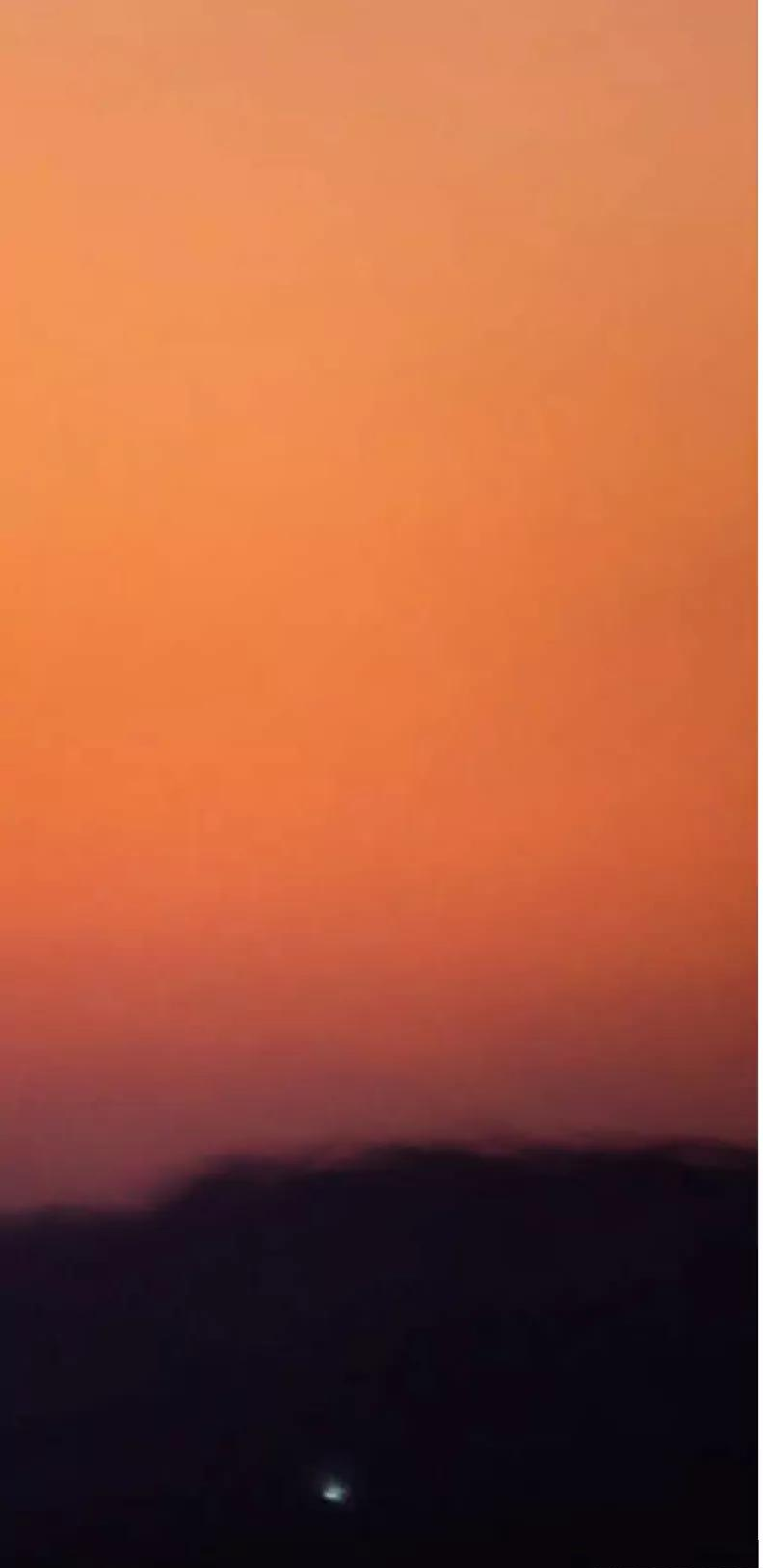
Procuring the Adir

Israel's interest in the F-35 fighter was born out of the necessity to replace its fleet of F-16 Fighting Falcons, which had entered service in the 1980s. The IAF initially used the F-16A/B 'Netz' ('Hawk'), which featured a unique stabiliser design plus extra countermeasures and an expanded range of ordnance options. This was followed by the F-16I 'Sufa' ('Storm') in the early 2000s – a modified variant of the two-seater F-16D Block 50 and 52 fighter and ground-attack aircraft, meaning that all Sufas are two-seaters. The modifications include changes to the aircraft's electronic systems as well as Israeli-designed conformal fuel tanks which increase the aircraft's overall tankage by 50%.

The Netz played a crucial role in Operation Opera in 1981 when the IAF destroyed the Osirak nuclear reactor in Iraq and was also instrumental in aerial combat during the 1982 Lebanon War. The Sufa has similarly been involved in numerous operations up to and including delivering munitions to destroy Hamas tunnel in Gaza.

Israel is creating four squadrons of F-35 fighters over the next few years. **Picture IAF**

Graduates on the 186th Flight Course pose with a historic Spitfire Mk.IX and the new F-35I. **Picture IAF**



Deliveries of the Sufa fleet commenced in 2004 but by that point Israel was already looking ahead to what might replace it. The Israeli Defence Ministry sent a Letter of Request to the US Congress in 2003, asking for authorization to purchase "up to" 75 F-35s, and a formal letter of agreement was signed which enabled Israel to join the System Development and Demonstration effort for the F-35 as a "security cooperation participant".

The deal, at that time, was worth $20m and Israel continued to pursue negotiations to operate, maintain and fit its own military systems to the aircraft.

Moving forward

Relations between Washington and Jerusalem turned sour at the beginning of 2005 however, after the US learnt of a potential arms deal between Israel and China. American defence officials said Israel had originally claimed it was maintaining Chinese drones when in fact it was upgrading them using technology that the US did not want to fall into Chinese hands.

Trade sanctions were imposed and Israel was removed from the F-35 programme. By June 2005, Israel had cancelled the drone upgrade deal with China and allowed the US to examine its defence exports. Subsequently, the Israelis were allowed to resume their F-35 acquisition.

A $2.75 billion deal was signed for 19 F-35As in 2010, with $475 million of that being non-recurrent costs for the integration of Israeli systems. By July 2011, the talks to determine exactly what Israeli Aerospace could change and manage had moved forward and the US had agreed to allow Israel to install its own electronic warfare systems and missiles in its F-35s.

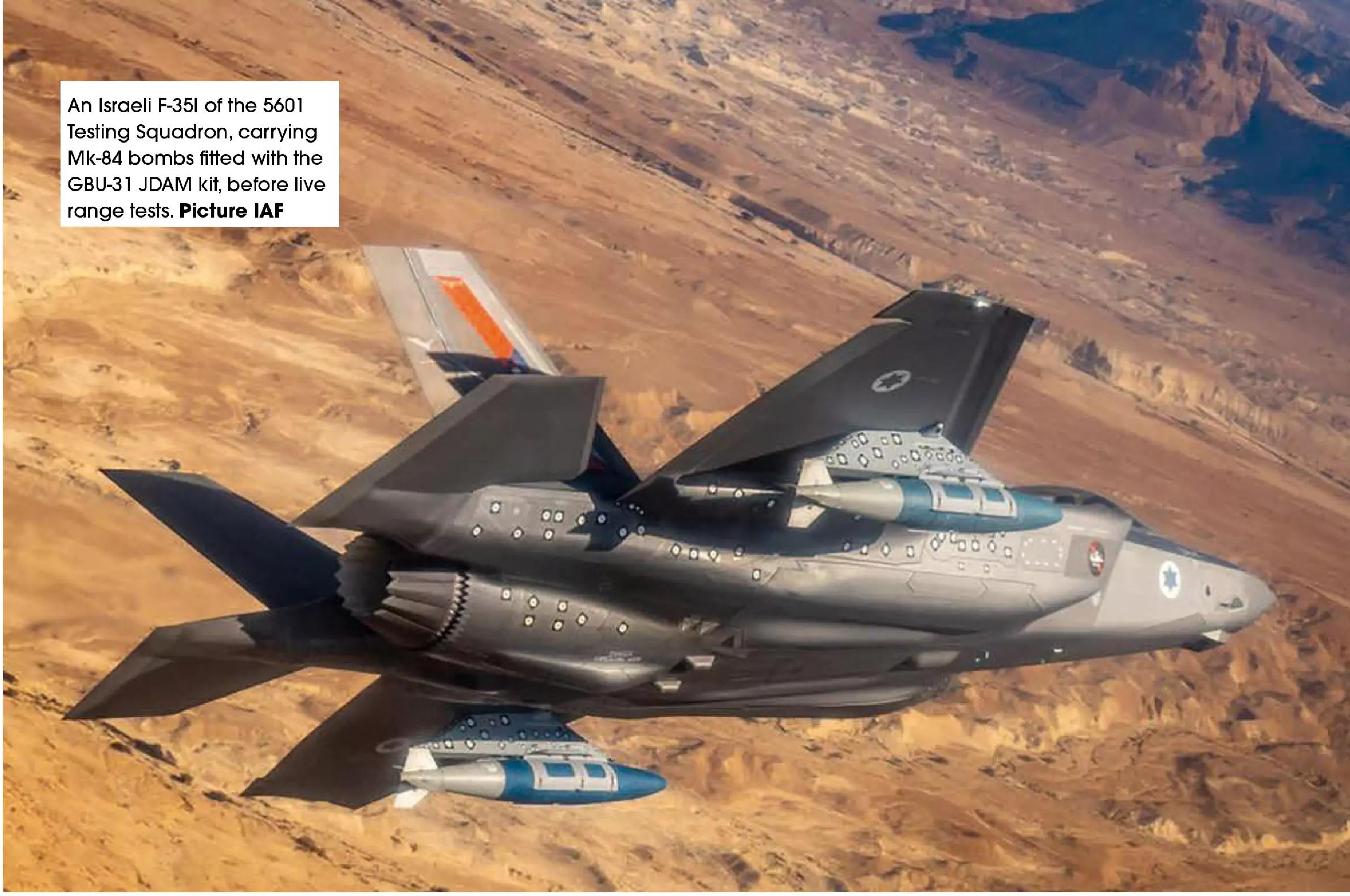
A year later, Lockheed was awarded a contract to make changes to the first Israeli F-35s and allow the installation of Israeli electronic warfare equipment, produced by the Israeli company Elbit Systems. Israel also secured an agreement to integrate its own home-produced guided bombs and air-to-air missiles into the aircraft. A senior Israeli described the technology they planned to add as being like an iPhone App that would run on top of the aircraft's main avionics. In addition, Israel would build 811 sets of F-35 wings under licence, with the construction of a new factory and the creation of hundreds of jobs.

Israeli F-35I #905 with its green formation lights lit up. Also known as 'slime lights' these consist of a thin film of electroluminescent light normally used to assist pilots when flying in formation in low visibility environments. **Picture IAF**

901
RESCUE
TURN FWD MASTER LA
AND AFT MASTER LA
TO OPEN DOOR
CAUTION-HOT
CAUTION-HOT

Israel received its first two fifth-generation F-35 Joint Strike Fighters after negotiating the 'fitting' of its own system and naming the aircraft the Adir. **Picture IAF**

Israel has 45 F-45I Adirs in service with 30 more on order and an expectation that it will eventually field 100. **Picture IAF**



An Israeli F-35I of the 5601 Testing Squadron, carrying Mk-84 bombs fitted with the GBU-31 JDAM kit, before live range tests. **Picture IAF**

In the same year, the Israeli company Rafael Advanced Defence Systems was contracted to develop smaller versions of its Python and Derby missiles for carriage within the aircraft. In addition, Israel Military Industries was to develop a penetration bomb similar to the Mk 82 500lb munition, but the project was delayed as the IDF wanted the F-35 in service in order to be ready to counter any threats from Iran.

The first squadron of 20 F-35s, from the first production series, only included a few Israeli-made systems. The United States agreed to allow the installation of more Israeli-made systems if Israel purchased further F-35 squadrons. In addition, Lockheed Martin said it would buy parts and systems for the F-35 from Israeli companies at a cost of $4 billion.

Planning and preparation

Israel started building the infrastructure needed to accommodate F-35s in 2013, including hardened aircraft shelters as well as underground 'bomb proof' shelters and maintenance facilities. The shelters, produced by US firm Conti Federal, would consist of reinforced concrete facilities, blast-resistant

Israel's F-35s have seen particularly heavy use ever since their entry into service. **Picture IAF**

Air-to-air refuelling is vital for extending the F-35's already impressive range. **Picture IAF**

steel sliding hangar doors, several thousand feet of underground utility corridors, complex mechanical and electrical systems and a computerised building management system. Contacts were awarded too for the construction of additional manufacturing facilities to produce the F-35 wing sets.

Final assembly of Israeli's F-35s took place at Lockheed Martin's Aeronautics Company in Fort Worth, Texas, while flight-testing was conducted at Fort Worth, Edwards Air Force Base and Naval Air Station Patuxent River. The IAF uses the Leonardo M-346 advanced jet trainer and light combat aircraft to prepare its F-35 pilots. This twin-engine, tandem-seat aircraft is able simulate the characteristics of fourth and fifth generation fighter aircraft and therefore is perfect for getting potential F-35 pilots up to speed before they fly to the United States.

In 2016, Israeli pilots began training on the F-35A alongside American pilots at Luke Air Force Base in Arizona. Here, they underwent simulator and ground-based training before being cleared to take to the skies. Once their initial training in the US was complete, they returned to Israel to continue their flight training on the F-35Is at Nevatim Air Base. The first nine F-35Is became operational with the Israeli Air Force in December 2017.

Just five months later, on May 22, 2018, the IAF announced that Israel had become the first country in the world to use the F-35 in combat, with aircraft taking part in air-strikes in Syria and Iran. Later they were deployed in Gaza, over the Lebanon and in air strikes against Houthi rebels, a Yemeni militant group backed by Teheran.

Adir operations

It was not until November 2020 that a bespoke, Israeli-designed F-35I testbed aircraft was delivered to the IDF, the only example of a testbed F-35 being delivered to any air force outside the United States. By November 2022, the IAF had 36 F-35s in service, including the testbed stationed at the Israeli flight test centre at Tel Nof and Nevatim airbases.

In 2023, Israel received yet more Adirs, bringing the total to 42, and at the same time placed an order for a further 25 aircraft. And in the same year, the

The first flight of Israel's new F-35 Joint Strike Fighter was soon followed by several operational missions. **Picture IAF**

The success of the IAF's strikes on Iran's air defence network have clearly demonstrated the F-35's stealth capabilities. **Picture IAF**

The USAF regularly trains with Israeli pilots to enhance their partnership and skills – especially after an upgrade has been added to the aircraft. **Picture IAF**

The ‘Adir’ is the only export version of the F-35 that can be modified outside of Lockheed Martin’s factory. **Picture IAF**

An F-35I Adir, part of Squadron 116, takes part in a training exercise. Israel’s air force holds its F-35s at permanent readiness. **Picture IAF**

An Israeli F-35I awaiting maintenance – Israeli F-35s do not have the pilot's name painted on their airframe, unlike those operated by the US. **Picture IAF**

Israeli F-35I Adir aircraft were able to totally evade Iranian air defence systems when they mounted air strikes against Tehran's nuclear sites in June 2025. **Picture IAF**

IDF successfully conducted wargames in southern Israel using the F-35I, arming the jets with bunker-busting JDAM-84 munitions to demonstrate their capability to strike hardened targets such as Iran's nuclear facilities.

Over the last few years, these Adirs have been used across the Middle East in both an offensive and psychological role. They have been observed flying over Lebanon, often in conjunction with other Israeli fighter jets such as the fourth-generation F-15. These flyovers are often interpreted as a display of strength and a message to Hezbollah, a group which it is claimed is a proxy arm of Iran and the most lethal of the Teheran-supported groups in the region.

In September 2024, Israeli Adir fighters bombed a building in Lebanon, killing Hassan Nasrallah, the then-leader of Hezbollah. At Nasrallah's funeral in Beirut, four F-35s flew at low altitude above the ceremony in what was widely interpreted as a form of intimidation. At the time the Israeli Defence Minister Israel Katz said the flyover was a direct message to those who threaten Israel. He said: "The Israeli Air Force aircraft currently flying over Beirut, over the funeral of Hassan Nasrallah, convey a clear message: Whoever threatens to destroy Israel and attack Israel – it will be their end." Since then, the IDF has increasingly used the F-35I in low-level flyovers across Lebanon in a bid to demonstrate Israel's aerial supremacy in the region.

At the start of October 2024, Teheran sanctioned an attack on Israel involving more than 180 ballistic missiles. Israeli air defences, supported by the US military, intercepted almost 90% of these projectiles, according to an Israeli military spokesman. The Israeli Government then vowed to strike back and on October 26 mounted one of the biggest air assaults the country has ever conducted. In a pre-dawn attack on selected targets deep inside Iran, 'fire and forget' munitions allowed the aircraft to avoid directly entering Iranian air space.

The Israeli retaliation came in three waves, with the first strike hitting at about 2am on October 26. Dozens of aircraft, including the F-35I Adir and supported by air-to-air refuelling aircraft and reconnaissance planes, left their bases before midnight on October 25, flew more than 1,000 miles and hit multiple targets including the regime's prized, Russian-provided S-300 air defence systems.

An Israeli source said four of the S-300 systems were hit, along with radars and other air defence capabilities, reducing the risk to Israeli aircraft should they be deployed on any future mission against the Iranian regime. Israeli officials said the raid, named Operation Days of Repentance, also targeted sites where Teheran was manufacturing missiles used to threaten Israel. No aircraft were lost or damaged in what was described as a 'complex' operation.

Open-source reporting indicates that Israel hit targets in around 20 locations across Iran, including

The F-35 has proved to be a major success for the Israeli air force ensuring it maintains air dominance in the Middle East. **Picture IAF**

WARNING - DO NOT CUT CANOPY
WITHIN 3 INCHES OF CANOPY FRAME
901
RESCUE
926

RESCUE
TURN FWD MASTER LATCH
AND AFT MASTER LATCH
TO OPEN DOOR
DANGER
JET INTAKE
NO STEP

An Israeli Air Force pilot climbs into an F-35I Adir at Nellis Air Force Base, Nevada, during evaluation exercises. **Picture IAF**

Boeing 707 'Ram' plane from the Desert Giants squadron refuels F-35I fighter jets during exercises. **Picture IAF**

close to Tehran and in the west of the country. The IDF said its aircraft went after missile manufacturing sites as well as Iranian air defence capabilities – including those S-300 systems. Degrading Iranian air defences will reduce the threat to Israeli jets on any future attack, while targeting Iranian missile manufacturing capabilities is intended to reduce the ability of the Islamic Revolutionary Guard Corps to strike back against Israel.

Israel has not publicly acknowledged the route for its operation but it is understood that the Israeli F-35I Adirs and F-16s flew over Syria and then into Iraq, firing their weapons from Iraqi airspace before returning. The Iraqi government made a formal complaint to the United Nations, accusing Israel of a "blatant violation" by using its airspace to attack Iran.

Current situation

Israeli military commanders see the Adir as giving the IDF the ability to both defend the nation and take the fight to the enemy. After years of failed political solutions to the Arab-Israeli issue, Israel continues to fear insurgent activity in Syria, Iraq, Iran, Egypt and Yemen. Ministers claim the growing instability in the Middle East has been fuelled by the potential threat from Iran's nuclear weapons project.

In addition, the region has seen the resurgence of Hamas, Hezbollah and the Houthis, united by their opposition to Israel's refusal to negotiate a future for millions of Palestinians. For Israelis, the Hamas attack of October 7, 2023 ignited the greatest threat to Israel's continued existence since the Yom Kippur War of 1973. This saw some 4,300 rockets launched into Israel, followed by vehicle-transported and powered paraglider incursions from Gaza into Israel.

Around 6,000 Gazan militants breached the border in 119 locations and poured into Israel – ultimately resulting in 736 Israeli civilians, including 36 children, being killed as well as 79 foreign nationals and 379 members of the Israeli security forces.

Since then, F-35I Adirs have been used on a number of occasions to strike at Hamas targets within Gaza, attracting a wave of protests from human rights campaigners. In February 2025, more than 230 global civil society organisations called on governments producing F-35 parts to immediately halt all arms transfers to Israel.

According to an Amnesty International press release: "Israel has used F-35 jets in its bombardment of Palestinians in Gaza. An F-35 was used in July 2024 to drop three 2,000lb bombs in an attack on a so-called 'safe zone' on Al-Mawasi in Khan Younis, killing 90 Palestinians … despite all partners to the F-35 programme having legal obligations to halt arms exports to Israel, governments continue to allow the transfer of F-35 parts to Israel. Incoherent positions have been put forward by governments including stating that arms licences to Israel have been suspended while allowing transfers under existing licences or supplying 'indirectly' via the US or other F-35 partners".

Human Rights Watch UK director Yasmine Ahmed said: "It is unconscionable that the UK government continues to supply weapons that end up going to the Israeli government, especially for the F-35 which has played a pivotal role in Israel's brutal bombing campaign. The government must close the loopholes and end its legal gymnastics – failure to do so displays either a misunderstanding of the government's legal obligations or a wilful disregard for them."

Israelis, for their part, believe that the one unifying factor in the Arab world is the wish to see the destruction of Israel. They claim that this tiny nation stands in the way of an Islamic aspiration of a global Caliphate that is believed will host the Islamic version of the Messiah, known as the Mahdi. Rightly or wrongly, Israeli commanders see the F-35I Adir as their primary weapon to stop what they see as terrorists and militants who wish to attack them.

The other nations buying the F-35 – the UK, Italy, the Netherlands, Turkey, Australia, Norway and Denmark – have spent years negotiating how much they'll be allowed to tinker with the jet. None have had the success that Israel appears to be achieving. Beyond the software integration, which may encourage other nations to push for their own concessions, Israel is expected to add fuselage-hugging conformal fuel tanks, which mount above the wings and close to the fuselage.

Though they could extend the fighter's range by up to 40 percent, the tanks will likely compromise the jet's stealth capability. But Israel's view may well be that they want their enemies to know they are coming. There are more problems ahead; Israel and Turkey are directly at odds over the post-Assad Syria, where Turkey wants to deploy military forces at the invitation of the new government in Damascus, and which Netanyahu and his government sees as a potential threat. Israel made its opposition clear by bombing the same Syrian airbases where Turkey planned to deploy long-range drones and air defences systems. There are plans for negotiations to allow both Turkey and Israel to operate alongside each other. However, fundamentally, Israel views Ankara's plan to establish a military foothold in central Syria as a strategic threat.

In the early morning of June 13, 2025, Israel launched an ambitious air campaign against Iran – aimed at disabling or delaying its nuclear programme. While much of the work will have fallen on Israel's fleet of 174 F-16C/Is and 66 F-15s, the offensive, dubbed Operation Rising Lion, is said to have heavily involved the nation's relatively small fleet of F-35Is, penetrating deep into Iranian airspace to hit particularly well-defended targets. A key target was Iran's largest uranium enrichment site in the Natanz area, with an IDF spokesman saying on the day of the attacks: "As part of the strikes, the underground area at the site was damaged, containing a multi-storey enrichment hall with centrifuges, electrical rooms and additional supporting infrastructure. In addition, vital infrastructure at the site that enables its operational continuity and continued advancement of the Iranian regime's nuclear weapons project were attacked." ■

Israeli F-35Is were part of a 200-strong wave of fighter aircraft which mounted attacks against Iran. **Picture IAF**

6

CHAPTER

Global Operators

The F-35 has been a global success for America with numerous allied nations viewing the fighter as the best option to replace their legacy fourth generation jets. Australia, Denmark, Israel, Italy, Japan, the Netherlands, Norway, South Korea and the UK are all operating the Lightning II, with still more countries signed up and awaiting deliveries.

The F-35 has been a global success for America. By mid-2025, 19 nations besides the US had procured the aircraft. **Picture US DoD**

The UK operates the F-35B and recently announced that it would also purchase the F-35A. **Picture US DoD**

F-35 operators

There were plenty of doubters at the beginning – those who felt that the F-35's stealth capabilities might not be enough to make up for its lack of outright speed and agility compared to older multirole platforms such as the F-16. But over time it has become clear that the F-35, despite ongoing difficulties with supply chain issues and operational availability, is a true next-generation platform and a supremely capable combat-proven multirole aircraft.

As of mid-2025, the list of nations signed up to the F-35 programme included not just those mentioned above but also Belgium, Canada, Finland, Germany, Greece, Poland, Romania, Singapore and Switzerland. Still more countries had been considering the F-35 but ended up without it for a variety of reasons: Taiwan, Thailand, Turkey and the United Arab Emirates.

An F-35 of the Japanese Self Defence Force pictured during an air-to-air refuelling mission. **Picture US DoD**

Officials from Singapore inspect an F-35. The first airframes are due to enter service with the Republic of Singapore's air force in 2026. **Picture US DoD**

Most nations opted for the F35A with the UK, Italy and Japan procuring the B variant – although both Italy and Japan also have the A variant in service. **Picture US DoD**

The Danish air force has taken delivery of its F-35As and is to review a further order. **Picture Danish Government**

UK

The UK initially planned to order F-35Cs, plus a small number of F-35Bs, for deployment on the nation's new Queen Elizabeth Class aircraft carriers. But during the 2000s politicians decided that the cost of fitting a catapult launch system on both carriers made the F-35C less attractive and the order was refocused exclusively on the F-35B instead.

The UK received its first F-35B in 2012 and made RAF Marham the primary base for the aircraft. Squadron Leader Steve Long became the first British pilot to fly an F-35 on January 26, 2010, and in July 2012 the Government announced its decision to purchase an initial batch of 48 aircraft.

At the time of writing, the UK had received 37 examples, although it lost one when it crashed into the Mediterranean. Britain has plans to increase its F-35 fleet beyond this initial order, with the government announcing in June 2025 that it intends to buy at least 12 F-35As capable of carrying both conventional and nuclear weapons.

The UK's F-35 programme is expected to cost over £18 billion over its lifetime, depending on the numbers and types the UK finally orders. The UK currently operates four F-35 squadrons, with the RAF's 617 'The Dambusters' Squadron forming the first and with 809 Naval Air Squadron having followed shortly thereafter. In addition, 207 Squadron is the Operational Conversion Unit working alongside 17 Test and Evaluation Squadron. 617 and 809 Squadrons are frontline operational units, with 207 responsible for training pilots and 17 Squadron conducting testing and evaluation

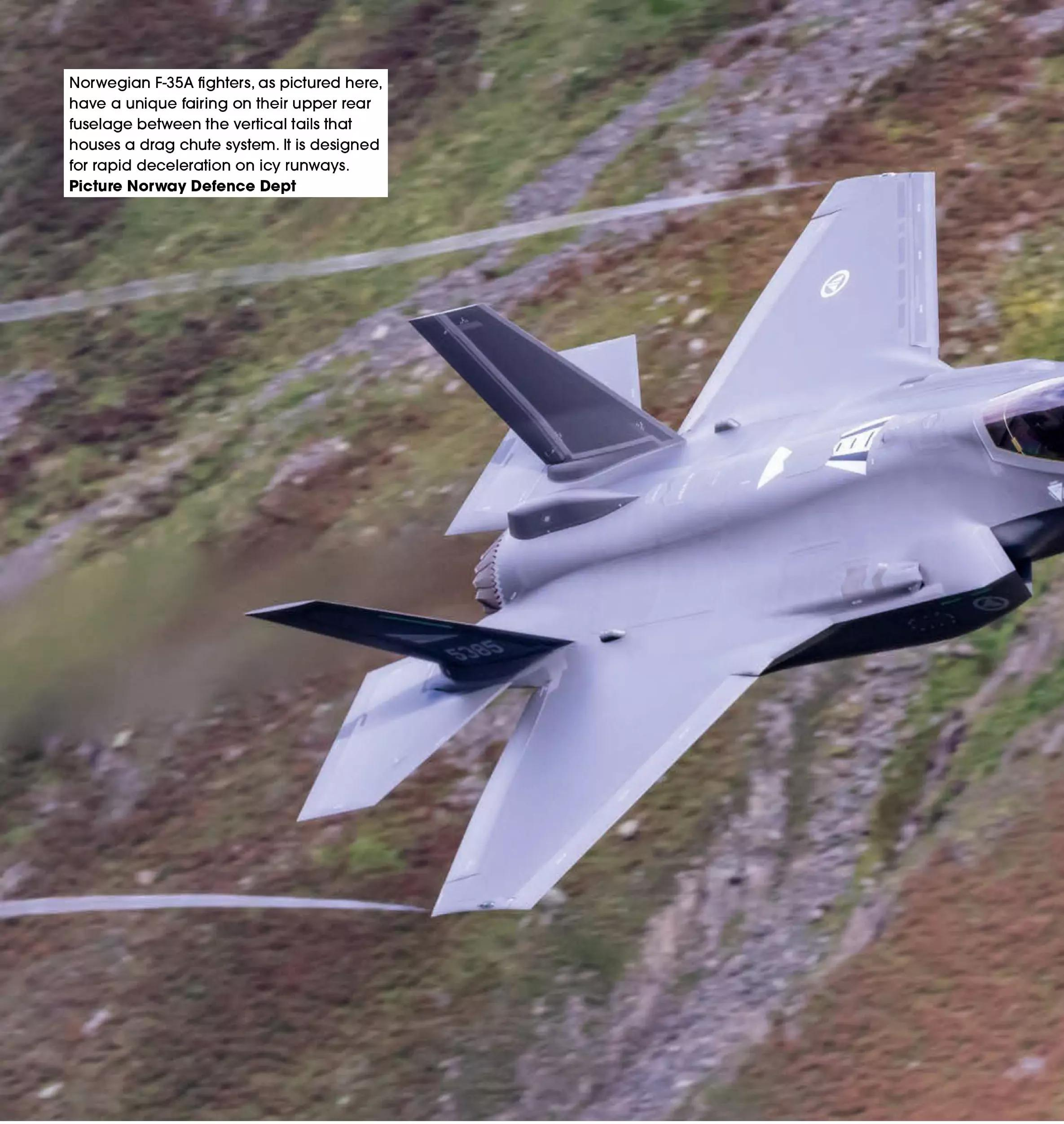
Italy

Italy is currently the only country outside the United States to operate multiple variants of the F-35 Lightning II: the conventional F-35A and the STOVL F-35B. The Italian Navy operates the F-35B from its flagship, the aircraft carrier ITS *Cavour*, which in early 2025 supported the Royal Navy's HMS *Prince of Wales* in pre-deployment training off Sicily, prior to the UK warship heading though the Suez Canal en route to the Indo-Pacific. In 2024, Italy revealed plans to significantly expand its F-35 force; it currently operates fewer than 30 but will increase that number to 115. This will include 60 F-35As for the Italian Air Force and 30 F-35Bs for the Navy, with some of those also being operated by the Air Force.

When all have been delivered, the Italian armed forces will be among the most prolific operators of the F-35 in NATO. Italian F-35s are actively involved in various operations, including NATO exercises and air policing missions. The Navy's F-35Bs took part in exercises such as Exercise MedStrike25, in which Italian fighters operated from HMS *Prince of Wales*. Additionally, Italian F-35s are supporting NATO's enhanced air policing mission in Poland.

Netherlands

The Royal Netherlands Air Force (RNLAF) is transitioning to the F-35A Lightning II fighter jet as its primary combat aircraft, replacing the F-16 which has been in use since 1979. The first F-35s paid a brief visit to the Netherlands in May and June 2016 as part of the development programme. A contract for eight additional F-35s was then signed in 2015, with the airframes being delivered from 2019 onwards. At the time of writing, the Dutch government was planning to purchase at least 46 new aircraft. The RNLAF currently operates two F-35A squadrons, No. 322 Squadron at Leeuwarden Air Base and No. 313 Squadron at Volkel Air Base. A third,


Norwegian F-35A fighters, as pictured here, have a unique fairing on their upper rear fuselage between the vertical tails that houses a drag chute system. It is designed for rapid deceleration on icy runways. **Picture Norway Defence Dept**

No. 312 Squadron, is also planned for Volkel but it is not yet fully operational.

The Dutch Government opted to invest in the F-35A instead of the F-35B due to a combination of strategic factors and existing infrastructure, as well as the nature of their NATO commitments which aligned better with the F-35A's capabilities. The RNLAF declared its F-35 force fully operational in late 2024 and today its aircraft contribute to various NATO operations, including the Alliance's enhanced air policing missions in Poland and Bulgaria.

Canada

After years of delay, Canada's then-Liberal government signed a contract with Lockheed Martin in June 2023 to purchase 88 F-35 jets. At the time, the country's Defence Department stated: "Today we are announcing that Canada is acquiring a new fleet of 88, state-of-the-art F-35 fighter jets, through an agreement that we have finalised with the United States Government and Lockheed Martin with Pratt & Whitney. The investment is estimated at $19 billion Canadian dollars, making it the

Three F-35s in service with the Royal Netherlands Air Force. The RNAF currently operates 40 airframes and is seeking to procure another 12. **Picture Royal Netherlands Air Force**

Dutch F-35 aircrew discuss a flying mission before getting airborne. **Picture Royal Netherlands Air Force**

largest investment in our Royal Canadian Air Force in 30 years."

The Canadian military plans to replace its current fleet of CF-18s with the F-35. The first batch of six aircraft is due to be delivered in 2026 and the order is part of a larger effort to modernise the Canadian Air Force and ensure compatibility with NATO allies. The future of the F-35 order was briefly put in doubt when Washington imposed major tariffs on imports from Canada, but industry analysts have indicated that the procurement will still go ahead as planned.

Australia

The final nine of Australia's fleet F-35As landed at the Royal Australian Air Force base in Williamstown, New South Wales in December 2024. The first of the country's 72-strong order had arrived in Australia on December 10, 2018 as part of a major capability upgrade to the Air Force, and the first F-35A unit, No.3 Squadron, became operational in 2021. Australia's commitment to 72 aircraft provides it with three operational squadrons, with two based in the Melbourne suburb of Williamstown and one at Tindal in the Northern Territories.

Dutch F-35As taxi onto the runway. **Picture Royal Netherlands Air Force**

A Dutch F-35 under armed escort to make sure its advanced systems are safeguarded. **Picture Royal Netherlands Air Force**

The RAAF plans to integrate its F-35A fleet with its existing EA-18G Growler and F/A-18F Super Hornets, as outlined in the nation's 2024 National Defence Strategy. But the Federal Government has confirmed it has put on hold plans to buy a fourth squadron of F-35s and will instead redirect some of that investment towards long-range missiles. The delay in future F-35 orders comes as the Defence Department decides to upgrade the Super Hornet fleet and keep it flying until 2030.

Denmark

Like many countries across NATO, Denmark ordered the F-35 to replace its F-16 fighters. After a review of the available options, the Danish Government announced its decision to order 27 aircraft in June 2016 and the first F-35 was delivered to the Royal Danish Air Force in 2021. By

An Australian F-35A.
Picture US DoD

Dutch F-35 taking part in low level training. **Picture Royal Netherlands Air Force**

Two Australian F-35As escort two B-2 bombers as they wait to start an air-to-air refuelling. **Picture US DoD**

The Royal Australian Air Force is due to have 72 F-35As in service. **Picture US DoD**

2025, 15 aircraft had been delivered and are now stationed on Danish soil. The remaining aircraft will arrive with Lockheed Martin's latest systems upgrade completed. Known as the Technology Refresh 3 upgrade, or TR-3, it will provide more computing power and capability for the aircraft. There is an option for Demark to order more aircraft, with the final costing estimate at $10 billion US dollars.

Norway

Along with its Scandinavian neighbour Denmark, Norway selected the F-35 to replace its F-16s, ordering 52 aircraft in the A variant. The country was the first to receive all of its planned aircraft and the first to have them all cleared for operations. The Norwegian F-35 fleet will be used for both national defence and NATO operations, including in the Arctic and High North regions.

Israel

As noted in Chapter 5, the state of Israel is the only country to have procured a bespoke aircraft – and the country to have made the greatest use of its fleet in combat so far. In particular, the Israelis have pioneered the use of the F-35's so-called 'beast mode', with munitions and stores mounted externally on underwing pylons.

The first F-35I Adir was delivered to the Israeli Air Force in December 2016, and since then Israel has continued to expand its fleet, with potential plans to operate a total of 100 aircraft. A key modification to the F-35I Adir is its electronic warfare suite, which was developed by Israeli defence companies. Advanced sensors and countermeasures allow the aircraft to operate in contested environments and counter enemy threats. For Israeli commanders there is only one issue with the Adir – that they don't have enough of them.

Japan

Japan's F-35 order includes a total of 147 aircraft, with 105 being of the F-35A variant and 42 being F-35Bs. Japan selected the 'A' variant to meet its strategic requirements, with the F-35B variant chosen to support the country's Maritime Defence Force. Tokyo has experienced a small delay in the delivery of the F-35A, primarily as a result of the complex TR-3 upgrade.

Japan is reportedly considering the acquisition of more F-35 stealth fighters from the United States as an option, should there be delays to the Global Combat Air Programme (GCAP), its joint sixth-generation fighter project being undertaken in partnership with the UK and Italy.

Republic of Korea

A close ally of the United States, the Republic of Korea (South Korea) has ordered 40 F-35As with an agreement to purchase another 20. The first 40 F-35As were delivered in 2019, and the additional 20 are expected to be operational by 2027. South Korea ordered the F-35A Lightning II to enhance its combat air capability and to deter aggression from North Korea, particularly given the latter's nuclear and missile threats. The F-35 is also seen as crucial for strengthening the country's pre-emptive strike programme and increasing its overall defensive capabilities against an attack from Pyongyang. Additionally, the order

Australian air force mechanic oversees an F-35 as it starts up. **Picture RAAF**

was driven by a desire to modernise the Republic of Korea Air Force and improve its operational capabilities, especially in response to the introduction of stealth fighters by, for example, China.

Belgium

Belgium has boosted its air force's capability with the procurement of the F-35A. Initially, the country ordered just 34 F-35As but now plans to acquire an additional 21, bringing the total potential fleet to 55. Notably, in May 2025 Belgium opted for European assembly of the additional jets at the Leonardo-Lockheed Martin facility in Cameri, Italy, rather than in the US.

Belgium is expected to announce full operating capability of its F-35s by 2027 and the aircraft is expected to significantly enhance the nation's contribution to NATO operations, particularly air policing over eastern Europe.

Poland

Poland has ordered 32 F-35As and will name the aircraft 'Husarz', the Polish word for Hussar. Unlike Israel, who also renamed their F-35s, the Polish aircraft will not include custom changes for Polish weapons systems. The first Polish F-35 pilots began training in the US in 2025 and delivery of the first aircraft is due in 2026, with the order due to be complete by 2030.

Singapore

The Republic of Singapore Air Force (RSAF) ordered a total of 20 F-35 aircraft, comprising 12 F-35Bs and eight F-35As. Initial deliveries of the F-35As are scheduled for around 2030, while deliveries of the F-35Bs are expected to begin in 2026.

The Pacific nation is replacing its aging F-16s to increase its defence capability, with commanders expecting

to use the B variant in support of ground operations and the A for strategic operations,

Finland

The Government in Helsinki ordered the F-35 as part of a boost to its military capability amid concerns of an incursion by Moscow across what is known as the 'northern gap', the area in the High North which sits alongside the Russian border. Finland has ordered 64 F-35As to replace its older F/A-18C/D Hornet fleet after the Fins held a competitive review called the HX fighter competition. These F-35As are being manufactured in lots and are scheduled for delivery from late 2025, with the first aircraft entering service in 2026.

Switzerland

Switzerland finalised a contract in 2022 to purchase 36 F-35A Lightning II fighter jets from Lockheed Martin at a cost pf $6.5 billion dollars. The aircraft are intended to replace the Swiss Air Force's aging F/A-18 Hornet and F-5 Tiger fleets, with deliveries expected to begin around 2028. In negotiations, the Swiss secured an agreement that requires Lockheed Martin to conduct business with Swiss companies, worth approximately 2.9 billion Swiss francs.

Germany

Germany ordered a total of 35 stealth aircraft from Lockheed Martin in 2022, opting for the A variant. The first examples are scheduled to be delivered in 2026 and once fielded, the Luftwaffe will join Norway, Japan and Australia as operational users of the Joint Strike Missile (JSM). Norwegian company Kongsberg says the Joint Strike Missile offers advanced capabilities for low-observable aircraft like the F-35. Designed for internal carriage, the missile preserves the F-35's low radar cross section (RCS), a critical advantage in contested airspace. The stealth profile is compromised when weapons are mounted externally due to exposed edges that reflect radar energy, making the aircraft more visible to air defence systems.

Czech Republic

The Czech Republic has agreed to purchase a total of 24 F-35A aircraft, part of a larger deal with the United States which includes training, logistics and other support services. The F-35 was

The Italian defence department ordered both the F-35A and B variants. **Picture US DoD**

Italy has operated some of its F-35B aircraft from the deck of the carrier HMS *Prince of Wales*. **Picture US DoD**

chosen as the successor to the nation's Saab Gripen fighters, with the aim of replacing them by 2035. This decision is viewed as a strategic necessity, as the F-35's fifth-generation capabilities are seen as crucial for future battlefields. The first batch of F-35s is expected to be operational by 2029, with the entire order to be fulfilled by 2035.

Greece

After years of cutbacks to defence following the collapse of the country's economy in 2008, the Greek government has begun a major programme of investment that is highlighted by the order of the F-35A. Greece has procured the 20 aircraft in a $3.6 billion deal to raise its profile within NATO and deter potential threats from regional rivals such as Turkey. The administration in Athens has an option to order a further 20 aircraft. Delivery is expected to be completed by 2033, with the first jets potentially delivered in 2028.

Romania

Romania became the twentieth nation to join the F-35 family when it placed an order for 32 F-35As in 2024. The Romanian Air Force plans to use the F-35 to replace its F-16 MLU (Mid-Life Update) fighter fleet and will integrate with the existing F-16 fleet, enhancing Romania's air capabilities and NATO interoperability. The plan is for the F-35s to replace the F-16s between 2034 and 2040.

International cooperation

At this point, the entire Western world has bet its future security – perhaps its very survival – on the F-35. Back in 2020, the American think tank RAND produced a report which stated that Russian political and military leaders were becoming increasingly concerned about NATO's advantage in military aviation thanks to the proliferation of the F-35. It was noted that by 2025 the number of F-35s in service across Europe would "exceed the number of US fifth-generation aircraft stationed in the

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The US, Britain, Italy and Japan will operate the F-35B from floating carrier platforms. **Picture US DoD**

F35A screams low and fast as it takes to the air during a visit to Belgium. **Picture US DoD**

An F-35C flashes past the deck director, known as the shooter, during carrier operations in the Pacific. **Picture US DoD**

European theatre by a wide margin". Russia, on the other hand, was struggling to even put its home-grown Sukhoi Su-57 fifth-generation fighter into service.

The RAND report noted that Europe's fourth generation aircraft would suffer significant losses during a high intensity conflict with Russia thanks to its advanced surface-to-air missile defences, stating: "During the opening phases of a conflict with Russia, vulnerability to advanced ground-based threats would constrain the roles of most fourth-generation and so-called fourth-generation-plus platforms. As long as an extensive threat persisted, more advanced platforms such as the Rafale or Eurofighter could theoretically perform strike missions inside the threat zone in conjunction with fifth-generation platforms, although this approach could yield unacceptable attrition".

However, it was suggested that European legacy fast jets could effectively be used as 'missile trucks' – getting advanced munitions into the air and close enough to their targets so that they could be guided the rest of the way by fifth-generation fighters.

The report state: "In the 'combat ISR' mode, a four-ship flight of F-35s connected by their multifunction advanced data link (MADL) generates situational awareness and shares targeting data with legacy platforms that can then fire their payloads from outside the range of the most capable of the enemy's air defences".

Given that all F-35s feature the stealthy and secure MADL, operational communications and cooperation between aircraft of different nations should be more seamless than ever before – making a large European force of F-35s operating together a real force to be reckoned with.

The competition

Both Beijing and Moscow have developed fighters designed to challenge the F-35, although it is not clear how capable either would be when up against the Lightning II. The Chinese equivalent of the F-35 is called the Shenyang J-35 and Beijing claims this single seat, twin-engine, all-weather fighter incorporates advanced stealth capabilities.

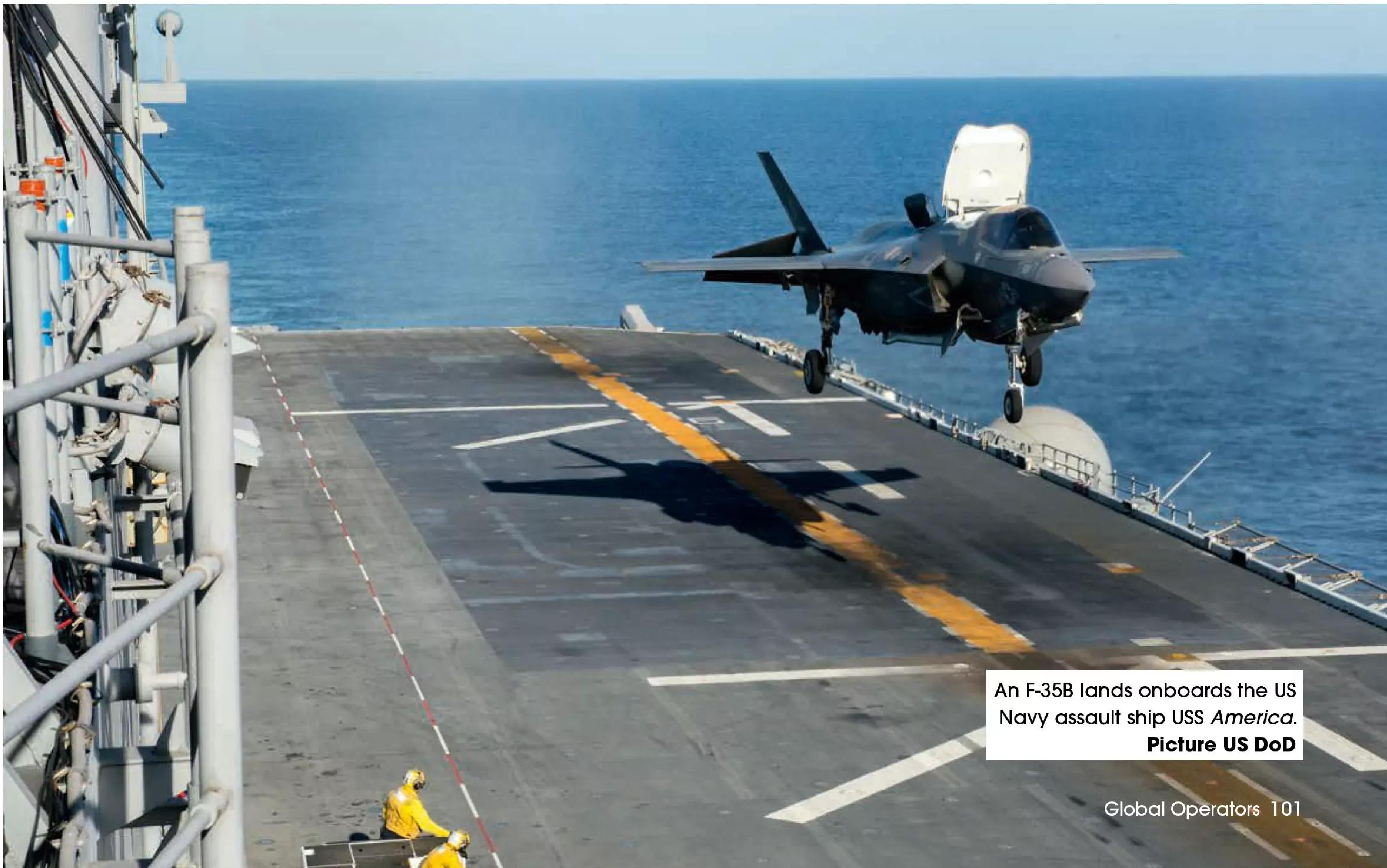
However, there is evidence that China stole American F-35 secret when working on the J-35 – the mere fact that it looks so much like a twin-engine F-35 perhaps providing some clue as to the origins of its design. In March 2016, a 50-year-old Chinese national pleaded guilty to charges associated with what the United States Justice Department described as a 'conspiracy' conducted in concert with high-ranking members of the Chinese military to steal military secrets, most notably, the designs for the F-22 and F-35 advanced stealth fighters.

China began formal development of its first stealth fighter, meant to compete directly with the F-22 and F-35 in 2008, awarding the Chengdu Aerospace Corporation a developmental contract. The J-35A, a land-based variant, was unveiled at the Zhuhai air show in November 2024, but it has yet to enter frontline service, and its operational deployment timeline is uncertain.

The J-35 naval variant is in development for operations aboard aircraft carriers, using a catapult launch system. This J-35 variant is expected to copy the F-35C and incorporate folding wings, a tailhook for arrested landings, and a launch bar for catapult launches. But the Chinese J-35 has not been combat-tested and very little has been seen of it, with analysts indicating that the project's in-service date' is currently delayed.

Russia's answer to the F-35 is the powerful Su-57. This twin-engine stealth fighter has a range of 1,500 miles, and according to Moscow is packed with technology. But in reality, the Su-57 is said to lack the cutting-edge design of the F-35 – particularly where all-round stealth capability is concerned.

The Russian aircraft has been deployed in Syria and Ukraine. In Syria, it was used for reconnaissance flights and high-altitude air-to-ground missile launches between 2018 and 2020, but these deployments were not extensive. In Ukraine, the Su-57 has been used to launch 'fire and forget' missiles into Ukrainian territory. It is estimated that Russia has between 22 and 42 Su-57s in service, but the political embarrassment that would follow an Su-57 being shot down over Ukraine has restricted its use. In June 2024, a Ukrainian drone team attacked several Su-57s at Akhtubinsk airfield in Astrakhan Oblast. Ukraine's GUR, the Main Directorate of Intelligence of the Ministry of Defence of Ukraine, claimed to have hit one while it was parked on the apron of the airfield more than 450 miles from the front line. ■



An F-35B lands onboards the US Navy assault ship USS *America*. **Picture US DoD**

7

CHAPTER

F-35 on Operations

The first combat operations for Washington's new stealth fighter took place in May 2018 when F-35I Adirs operated by the Israeli Air Force mounted air strikes in Syria against Islamic insurgents. The first American mission was carried out by the US Marine Corps in September of the same year when three aircraft hit Taliban militants in Afghanistan and Islamic State Fighters in Syria. The USAF's first F-35A combat operation was in April 2019 in Iraq, targeting ISIS infrastructure, and the UK's F-35Bs went into action against Islamic State in 2021. Then in November 2024, the F-35C variant, flown by the US Navy, participated in airstrikes against Houthi targets in Yemen.

The first combat operations for the F-35 took place in May 2018 when the Israeli Air Force mounted air strikes in Syria against Islamic insurgents. **Picture IAF**

First into action

Israel was the first country, even before the United States, to mount a combat mission with the F-35. The operation took place on May 22, 2018, and is understood to have involved an airstrike on Iranian military hardware identified in Syria. At the time, Israel's Air Force commander, Major General Amikam Norkin, announced: "Israel became the first country in the world to use the F-35 in combat during recent clashes with Iran in Syria. The F-35 squadron has become an operational squadron. We are flying the F-35 all over the Middle East." The air-strike came after Iran fired more than a dozen missiles into Israel from bases used by its proxy militants Syria. In response, the Israeli Air Force (IAF) attacked over 20 Iranian targets in Syria, destroying missile sites and more than a dozen air defence systems. It is understood that a pair of F-35I Adirs used JDAMs to hit the targets.

Israel procured the F-35 to ensure it maintained its aerial superiority and its technological advantage in the region. No other country in the region has the same capability; although Iran was still able to operate a small number of Grumman F-14s – at least up to June 2025 – Teheran struggled to maintain them. Syria had a nominally strong force of Su-22 and -24s as well as MiG-23s and -29s up to November 2024 but the collapse of the Assad regime saw many destroyed.

Israel's early combat operations with the F-35 were closely studied by aviators in the US and just a few months later the US Marines Corps was in action with the F-35B. In September 2018, F-35Bs from Marine Fighter Attack Squadron 211 were embarked aboard the Wasp-class amphibious assault ship USS *Essex* (LHD 2) as part of Essex Amphibious Ready Group. On September 28, 2018, the squadron launched air strikes against identified Taliban targets in Afghanistan in support of Operation Freedom's Sentinel. This was the official name for the last major US military mission in Afghanistan and succeeded Operation Enduring Freedom (OEF). It began on January 1, 2015, and was concluded in August 2021, when US and allied nations left Afghanistan, evacuating thousands of civilians in a major airlift.

The historic mission by the USMC F-35Bs was marked by Colonel Chandler Nelms, commanding the 13th Marine Expeditionary Unit (13th MEU), when he said: "The opportunity for us to be the first Navy, Marine Corps team to employ the F-35B in support of manoeuvre forces on the ground demonstrates one aspect of the capabilities this platform brings to the region, our allies, and our partners."

F-35A first mission

The first combat mission for the US Air Force's F-35A aircraft took pace on April 30, 2019, when two aircraft targeted an ISIS tunnel network in Iraq.

The aircraft, normally based at Hill Air Base in Utah, had been pre-positioned to the United Arab Emirates and used JDAMs to destroy the target. The mission marked the first time the aircraft had demonstrated its capabilities in a strike against a designated enemy target. Operating in support of Combined Joint Task Force – Operation Inherent Resolve, the F-35As were called in to target and destroy a Daesh tunnel network and weapons cache deep in the Hamrin Mountains, close to the Iranian border. Lieutenant Colonel Yosef Morris, the commander of the 4th Fighter Squadron, said: "These aircraft have the ability to gather, fuse and pass so much information. That, combined with low-observable technology, allows us to really complement any combined force package and be ready to support contingencies."

First UK strike mission

The first UK F-35B operational task was flown on Sunday, June 16, 2019, in support of Operation Shader, Britain's contribution to the global coalition to counter Islamic State in Iraq and Syria. The two aircraft from 617 Squadron were operating from the aircraft carrier HMS *Queen Elizabeth* in the Mediterranean, working with NATO allies and partners, and the strike took place as the jets conducted a routine patrol over Syria. Subsequent F-35 combat missions from the *Queen Elizabeth* were conducted as part of the UK's Carrier Strike Group's operation in the fight against Daesh.

At the time the carrier strike group had 18 RAF and US Marine Corps F-35B jets embarked in what was the first major deployment of the new F-35B. Captain James Blackmore, who commanded the Carrier Air Wing said: "The

F-35Bs aboard the Royal Navy carrier HMS *Queen Elizabeth* went into action in Syria in 2021. They had been tasked as part of a Coalition mission against Islamic State. **Picture US DoD**

USMC F-35Bs were launched from the assault ship USS *Essex* and used JDAM bunker busters against their targets. **Picture US Marines**

The US Marine Corps carried out America's first operational F-35 mission in September 2018, when three aircraft hit Taliban militants in Afghanistan and Islamic fighters in Syria. **Picture US Marines**

The first F-35A combat operation was in April 2019 against an ISIS tunnel network, during which they refuelled from US Marines tankers. **Picture US DoD**

Lightning Force is once again in action against Daesh, this time flying from an aircraft carrier at sea, which marks the Royal Navy's return to maritime strike operations for the first time since the Libya campaign a decade ago. With its fifth-generation capabilities, including outstanding situational awareness, the F-35B is the ideal aircraft to deliver precision strikes, which is exactly the kind of mission that 617 Squadron has been training for day-after-day, night-after-night, for these past few months."

F-35C hits Houthis

The F-35C recorded its first operational strike in November 2024, when stealth fighters from the Marine Corps squadron VMFA 314 mounted multiple sorties against Houthi weapons storage facilities across Yemen. At the time the squadron was embarked aboard the Nimitz-class aircraft carrier USS *Abraham Lincoln* on a deployment in the Middle East. For almost ten months, the Iranian-backed Houthis had attacked merchant shipping in the Red Sea and threatened to attack US Navy warships. Intelligence reports from Central Command (Centcom) highlighted that the identified targets housed conventional weapons, including anti-ship missiles, many of which had been supplied by Teheran.

Aboard the *Abraham Lincoln*, Lt Col Jeffrey 'Wiki' Davis, commanding officer of VMFA-314, said: "The F-35C demonstrated its warfighting advantage by transiting contested airspace and striking targets in the heart of Houthi territory over multiple days. My Marines are honoured to be first to fight with the F-35C." Known as the 'Black Knights',

JDAMs – Joint Direct Attack Munitions – were used penetrate the insurgents' command cell deep inside a mountain range.

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The Israelis sought air dominance in the region with their F-35 against such neighbours as Iran who had purchased the F-14 Tomcat from the US back in the 1970s. **Picture US DoD**

Prior to the collapse of the the Syrian regime, Israel was also concerned that Syria could attack its territory with its Russian supplied Su-24s. **Picture US DoD**

JDAMs were used by F-35As to target and destroy a Daesh tunnel network and weapons cache deep in the Hamrin Mountains, close to the Iranian border. **Picture US DoD**

VMFA-314 are based at Miramar in California and transitioned from the F/A-18 to the F-35C in 2020, making them the first fleet squadron in both the Navy and US Marine Corps to operate the aircraft. Previously, VMFA 314 was also the first operational Marine squadron to fly the F-4 Phantom II and F/A-18 Hornet.

NATO operations

The F-35 is set to play a major role in NATO's future air policing initiatives, which aim to preserve the security of Allied skies. Denmark, Norway and the UK have already deployed F-35s to intercept Russian aircraft over the Northern North Sea and High North. This collective task for the Alliance involves the continuous presence – 24 hours a day, 365 days a year – of fighter aircraft and crews, which are ready to react quickly to possible airspace violations. Both Norway and Denmark are already integrating their F-35s into what is called the 'quick reaction alert' off the Scandinavian coast and into the High North.

Since March 2025, Danish F-35s are being integrated into Quick Reaction Alert (QRA) missions to protect Allied air space in the north of Europe. These missions are part of a broader shift, where F-35s are taking over some air-policing tasks from the aging F-16 fleet. The F-35 is also being used in Multi-Domain Operations (MDO) demonstrations, proving its ability to share data and connect with other allied forces The Danes recorded their first operation to shadow a Russian bomber out of Allied airspace in late March 2025.

Norway is also deploying F-35 jets on operations to protect the High North. In February 2025, two Russian Tu-95 Bear-H bombers escorted by two Su-33 Flanker-D fighters flew close to NATO air space up in the High North. According to the Norwegian Defence Department, the F-35 pilots quickly located and identified the Russian aircraft and maintained a safe but vigilant distance, enabling them to closely monitor the Russians' movements. The F-35's advanced capabilities allowed them to gather important information and ensure that the Russian aircraft did not violate NATO air space.

Major General Øivind Gunnerud, Norway's Air Chief, said: "Our QRA mission in the High North is important for our national defence and NATO's collective security. The ability to respond swiftly ensures the safety of our airspace and highlights the strength of our allied forces in maintaining peace and stability."

NATO's most sensitive air policing operation, known as Enhanced Air Policing, focuses on the Baltic region and involves a dedicated NATO air force detachment, drawn from countries across the Alliance. As they become available, F-35s from nations such as Belgium, Netherlands, Norway and Denmark will join the mission and deploy to guard the skies of Lithuania, Latvia and Estonia. Allies take turns deploying to air bases at Šiauliai in Lithuania and Ämari in Estonia on a four-month rotational basis.

An American F-35A pilot displays the Stars and Stripes. **Picture US DoD**

When the three Baltic States joined NATO in 2004, NATO's air policing capability was established at Šiauliai. In 2014, after Russia's illegal and illegitimate annexation of Crimea, the air policing presence was expanded to Ämari. Incursions into allied air space have been common and have often involved Russian aircraft, such as a pair of Ilyushin Il-20M Coot-A intelligence aircraft flying close to or on the edge of European air space.

As well as the Baltic States, NATO operates an Enhanced Air Policing operation on NATO's eastern flank across the Eastern Adriatic and Western Balkans. Here Hungary and Italy provide support to Slovenia's air space, while Italy has deployed F-35s to Poland and Iceland to support NATO's Air Policing mission.

Greece and Italy protect the airspace of Albania, Montenegro and North Macedonia, and further west, the Alliance has periodically deployed fighter aircraft to Keflavík Air Base in Iceland to provide protection for Icelandic airspace. Prior to this, the United States conducted air policing as part of its military presence in Iceland from 1951 to 2006.

The Iceland Air Policing Mission is different from other regional assistance missions in that it does not permanently cover Iceland's air space. Instead, it typically involves a deployment of fighter aircraft from a NATO ally for a period of three to four weeks, three times a year. In 2015, Belgium, Luxembourg and the Netherlands (known collectively as the Benelux countries) signed an agreement to conduct joint air policing of their territories. Under this agreement, the Belgian and Dutch air forces defend the Benelux airspace on a rotational basis.

The only NATO nation not to operate the F-35 on operations in Turkey. Ankara's F-35 involvement was suspended and it was removed from the programme in 2019 after it purchased the Russian S-400 surface-to-air missile system. Turkey had planned to purchase 100 F-35s and President Recep Tayyip Erdogan believed that President Trump, in his first term of office, would ultimately allow him to have both the

S-400 missile system and F-35 US warplanes. But he was wrong.

Turkey has the second-largest army in NATO and is one of Washington's key allies. It also played an important role in the Syria conflict, providing arms and military support to some rebel groups, and is located in a strategic position, sharing borders with Syria, Iraq and Iran. But the White House was not prepared to sell the F-35 to an ally who was operating modern Russian air defence systems. In 2018 a spokeswoman at the White House said: "Unfortunately, Turkey's decision to purchase Russian S-400 air defence systems renders its continued involvement with the F-35 impossible. The United States has been actively working with Turkey to provide air defence solutions to meet its legitimate air defence needs, and this administration has made multiple offers to move Turkey to the front of the line to receive the US Patriot air defence system.

"Turkey has been a longstanding and trusted partner and NATO ally for over 65 years, but accepting the S-400 undermines the commitments all NATO allies made to each other to move away from Russian systems."

In his second term President Trump has spoken of the importance of Turley as an ally, with the suggestion that Ankara can still lobby for the F-35 if it agrees to stop using the S-400.

F-35Bs from the carrier HMS *Queen Elizabeth*, including USMC F-35Bs stationed aboard the UK warship, attacked Islamic State targets in Syria. **Picture US DoD**

Coalition aircraft carried out routine combat air patrols across Syria. **Picture US DoD**

As the situation in the Red Sea escalated and Houthi rebels in Yemen continued to attack merchant shipping, US aircraft carriers deployed to the region. **Picture US DoD**

US Navy F-35Cs were sent into action mounting night strikes at missiles and weapon sites inside Yemen. **Picture US DoD**

US carrier operations

US Carrier Strike Groups (CSG) are the floating airfields that in modern warfare will provide the platform for the F-35C to mount operations. These huge warships can carry as many as 60 fighter aircraft, with the air group consisting of F-35Cs and F/A-18 Super Hornets as well as EA-18 Growlers. CSG operations involve a wide range of missions, including projecting power ashore, maintaining sea control, protecting shipping, providing humanitarian assistance and conducting surveillance operations. CSGs are also crucial for establishing air superiority, defending against theatre ballistic missiles and supporting peacetime presence missions.

The CSG is composed of a combination of ships, submarines, aircraft and personnel to meet the mission requirement, as well as supporting an extensive range of operations from combat to peace time presence. By mid-2025 the US Navy had equipped four frontline carriers with the F-35C, the USS *Carl Vinson* (CVN-70), USS *Abraham Lincoln* (CVN-72), USS *George Washington* (CVN-73), and the USS *Theodore Roosevelt* (CVN-71). These are all Nimitz-class aircraft carriers that have been upgraded to support the F-35C's operational needs with specialist catapult and arresting equipment.

Additionally, the Navy's Wasp and America-class amphibious assault ships can carry the F-35B. The Wasp-class is designed to transport Marines and their equipment, while the America-class is designed as a lighter, more aviation-centric assault ship capable of operating a squadron of F-35Bs and other aircraft.

The US Navy typically maintains three or four CSGs at sea simultaneously, although this can be increased to five. The Fleet Response Plan requires that six CSGs be deployed or ready to go to sea within 30 days, with an additional two groups ready within 90 days.

UK carrier operations

The United Kingdom operates two Queen Elizabeth-class aircraft carriers which between them carry a squadron of 24 F-35Bs. Senior Royal Navy commanders have indicated that the fast-moving pace of drone and artificial intelligence technology could see a squadron of unmanned platforms also operating from the British carriers in the future.

But while other nations operating STOVL aircraft can also operate with the UK carriers, they lack full interoperability and US F-35C and French Rafale jets cannot land on the Queen Elizabeth class vessels. There remains a view that the Royal Navy made the wrong decision when it chose to adopt the F-35B and instead should have opted for full carrier operations with catapults and arrestors, as used aboard earlier carriers such as HMS *Ark Royal*. During the development of the Queen Elizabeth carriers, various configurations and aircraft options were considered but in September 2002 the Royal Navy recommended the F-35B.

Work on the carriers, with a focus on STOVL aircraft, proceeded until 2010 when the new Conservative/Liberal coalition government made the announcement that they were reviewing the option to configure the new carriers for CATOBAR operations. The plan required the purchase of expensive equipment to launch and recover the aircraft. It would also mean the purchase of the larger, though potentially cheaper, F-35C variant.

Israel's air assault on Iran began on June 13 and involved the F-35I Adir in strikes against Iranian nuclear installations. **Picture US DoD**

There was militarily and politically sound reasoning for the change of direction; the C variant could carry a bigger weapons payload and has greater range. And the change would ensure that the Royal Navy's carriers were fully 'interoperable' with the conventional carriers of their key allies, the US and France. The review quickly highlighted a major increase in costs and a delay in operational capability, as the F-35C itself was facing delays.

On May 10, 2012, the Defence Secretary Philip Hammond announced that the Government had decided against the concept of fitting a catapult and arresting gear due to the costs of the additional work. Speaking in the House of Commons, he said: "It has become clear that operational carrier strike capability, using the 'cats and traps' system, could not be delivered until late 2023 at the earliest, considerably later than the date envisaged at the time of the SDSR (Strategic Defence and Security Review) of 'around 2020'. Britain's carriers will have all-electric propulsion, and therefore will not generate steam like nuclear-powered vessels, so the catapult system would need to be the innovative electromagnetic version EMALS – the Electromagnetic Aircraft Launch System – being developed for the United States Navy. Fitting that new system to a UK carrier has presented greater design challenges than were anticipated.

"The decision taken in the SDSR to proceed with a carrier strike capability, despite the massive challenges we faced with the MOD's budget, was the right decision. The decision to seek to contain costs by going for "cats and traps" on a single carrier, with greater

Israel's army and air force commanders pictured in their command headquarters during the initial air raids. **Picture US DoD** interoperability with allies, and the cheaper carrier variant version of the JSF aircraft was also the right decision, based on the information available at the time.

"However, the facts have changed, and I am not prepared to accept a delay in regenerating Britain's carrier strike capability beyond the timetable set out in the SDSR. And I am not prepared to put the equipment plan, which will support Future Force 2020, at risk of a billion-pound-plus increase in the carrier programme and unquantifiable risk of further cost rises. So, I can announce to the House today that the National Security Council has decided not to proceed with the 'cats and traps' conversion, but to complete both carriers in the STOVL configuration. That will give us the ability to use both carriers to provide continuous carrier availability, at a net additional operating cost averaging about £60 million per year."

Many senior naval officers had presumed that the way forward to was split the order between F-35B and C variants, to fit the second carrier with EMALS and install it on the first vessel when she underwent her major overhaul. It was subsequently revealed, in 2021, that the Royal Navy was considering fitting catapults and arrestor gear to the Queen Elizabeth class aircraft carriers to enable the operation of Fixed Wing Unmanned Air Systems (FWUAS) to complement the F-35B Lightning.

Italian carrier operations

The Italian Navy deployed its carrier ITS *Cavour* to the Indo-Pacific with an embarked air-wing of F-35Bs and Harrier AV-8Bs during the second half of 2024. Headed by the *Cavour*, the Combat Strike Group (CSG) included the Italian Navy frigate ITS *Alpino* (F594) and French Navy frigate FNS *Bretagne* (D655). *Alpino* continuously escorted the carrier after it left Italy in June 2024. The Italian Navy multi-purpose combat ship ITS *Raimondo Montecuccoli* (P432) joined the CSG in Japan. The F-35Bs reached initial operational capability for sea-based expeditionary operations and the Italian Air Force will lead the F-35B's land-based operations.

The Italian Air Force primarily operates the F-35A variant but uses the B model for dispersed operations from expeditionary airfields, and sea-based operations from the *Cavour*. The carrier's air wing included two Italian Air Force F-35Bs, six Italian Navy F-35Bs, seven AV-8B Harrier IIs and two NH-90 helicopters. Rear Admiral Giancarlo Ciappina, who headed the CSG, said: "The campaign in 2024 was very fruitful for us to declare our initial operational capabilities of our F-35Bs, because all the training that we have been performing has composed the necessary frame for us to be able to operate the aircraft."

The Italian Navy has taken a unique approach in the transitioning from the AV-8B Harrier IIs to the F-35Bs. Because the target date for the F-35B to reach full operational capability for sea expeditionary-based operations is at least 2028; the AV-8Bs are expected to continue in service until then. Captain Dario Castelli, Carrier Air Wing Commander for the *Cavour*, said that unlike the US Marine Corps and the Royal Navy, which stood down AV-8B

One of the nuclear sites in southern Iran which the Israelis claimed to have hit. **Picture US DoD**

Iranians claimed Israeli was bombing Tehran in the same manner as it had hit Gaza. **Picture US DoD**

Iran hit back with a series of ballistic missiles and drone attacks. **Picture US DoD**

A smoking Iranian military installation hit by Israeli jets during an initial air strike. **Picture US DoD**

squadrons before reactivating them later as F-35 squadrons, the Italian Navy only has one Naval fighter squadron, which operates both aircraft concurrently.

French carrier operations

The French Navy has not purchased the F-35 but it typically deploys up to 24 Rafale Ms on its single carrier, the *Charles de Gaulle*, and is able to operate US warplanes from the deck – potentially including the F-35C, though at the time of writing this had not yet occurred. The French Carrier Strike Group has completed its first deployment in the Pacific, where the carrier saw US and Japanese aircraft landing on its deck. The French CSG included the *Charles de Gaulle*, the destroyer FS *Forbin* (D620), the frigates FS *Provence* (D652) and FS *Alsace* (D656) and fleet oiler FS *Jacques Chevallier* (A725). During Exercise Pacific Stellar, US Navy F/A-18 Super Hornets from USS *Carl Vinson* (CVN-70) and Rafale Ms from *Charles de Gaulle* flew cross-deck landings,

A French Navy spokesman said: "The French carrier was very interoperable with the US Navy aircraft as our catapult and arresting gear equipment are from the US and Charles De Gaulle's Landing Signal Officers (LSOs) train for two years in the US, making them familiar with directing US naval aircraft for landing."

Japanese carrier operations

Japan currently operates two Izumo-class helicopter carriers that are due to be converted into light aircraft carriers, capable of operating the F-35C which Tokyo is purchasing from the US. These are the JS *Izumo* and JS *Kaga*. While not 'full-fledged' aircraft carriers like US Navy's Nimitz-class, they are the first aircraft carriers built by Japan since the Second World War. In October 2024, a Lockheed Martin F-35B from the US Navy's Air Test and Evaluation Squadron 23 successfully landed aboard the JS *Kaga* off the coast of Southern California.

The flight was part of a joint effort by the US Navy and the Japan Maritime Self-Defence Force (JMSDF) to certify the converted vessel for flight operations with short take-off and vertical landing (STOVL) fixed-wing fighters. A Pentagon spokesman said: "Data that testers gather during these sea trials will be analysed and eventually inform decisions to enhance the capabilities of the Maritime Self-Defence Force, as well as contribute to improved interoperability between Japan and the US."

Captain Shusaku Takeuchi, commanding officer of the *Kaga*, describes the drills with his US counterparts as 'essential for strengthening Japan's defence capabilities'. He added: "This test does not merely enhance the capabilities of the Maritime Self-Defence Force, it also improves the interoperability between Japan and the US, strengthening the deterrence and response capabilities of the Japan-US alliance."

Modifications made to get the Japanese vessels ready for hosting F-35 fighters included expanding the surface area of the flight deck and painting the landing surface with heat-resistant materials to withstand the F-35B's Pratt & Whitney F135-PW-600 vector-thrust engine.

Iranian missiles hit an oil refinery in Haifa during the 12-day war. **Picture IDF**

Israeli F-35Is took part in a series of air strikes across Iran. **Picture IAF**

Operation Rising Lion

The Israeli Air Force launched a blistering series of attacks on Iran's nuclear sites and military installations on June 13, 2025. It was stated that 200 aircraft had been involved in the strikes, including F-15s, F-16s and F-35s. In a TV address, Israeli Prime Minister Benjamin Netanyahu claimed that the offensive, codenamed Operation Rising Lion, was designed to "roll back the Iranian threat to Israel's very survival" by inflicting as much damage as possible on Iran's nuclear programme.

It was reported that the F-35Is involved in the operation may have been modified with low-observable conformal fuel tanks – allowing them to strike deep within Iran without compromising their stealthy characteristics or requiring mid-air refuelling.

At the time, it was stated that the 200 aircraft had dropped more than 330 munitions on about 100 targets. Further sorties followed and as the offensive wore on, the Israelis released video footage of Iranian ballistic missile launchers being destroyed by airborne attacks. One video even showed a pair of Iranian F-14 Tomcats being blown apart by missile or bomb strikes. On June 16, the IDF declared that it had achieved 'full air supremacy' over Iran – indicating that both the Iranian Air Force and Iran's surface-to-air missile defences had been completely disabled.

Iran later claimed that at least two F-35Is had been shot down during Rising Lion, but then proceeded to release obviously AI-generated imagery in an attempt to corroborate the allegation.

While it is unclear exactly what role Israel's F-35s played in Rising Lion, as opposed to its F-15s and F-16s, it is clear that the Iranians were caught completely by surprise and that their air defences were entirely ill-equipped to deal with an attack which included fifth-generation stealth fighters. ■

8
CHAPTER
The Future

The F-35 has changed modern air warfare and set the standard for future fighter design. Its sensors gather huge quantities of data and provide the pilot with unparallelled situational awareness while its multifunction advanced data link facilitates a previously unseen degree of coordination with other battlefield assets. Its stealth capabilities allow it to attack before the enemy can respond and its adaptability enable it to complete a wide range of missions.

At $200 million per airframe the F-22 Raptor is the most expensive fighter ever produced for the USAF. **Picture US DoD**

Future concept

Aerospace analysts have suggested that by 2035 there will be at least one fully autonomous variant of the F-35. At the annual Bernstein's Strategic Decisions Conference in New York in May 2025, Lockheed Martin's Jim Taiclet indicated that a future F-35 could be 'optionally manned', stating that it was possible within a short time frame.

Lockheed noted that in 2023 an F-35 flew for 11 minutes after its pilot ejected over South Carolina, indicating that the aircraft already has limited autonomous functions. During '2023 incident', the pilotless aircraft continued on for 64 nautical miles, relying its autopilot to maintain a 'zombie state' of stable flight. In the aftermath of the incident, a US Marine Corps investigation concluded that the aircraft's extended unmanned flight was due to stability provided by the F-35's advanced automatic flight-control systems. The fact that the aircraft was able to fly, albeit it on 'accidental autopilot', is a clear indicator that such a feature could be part of a future upgrade package. The optionally manned feature is expected to be part of the 'fifth-generation plus' build of the aircraft.

At the same time, Lockheed revealed the potential of emerging technologies which could be used to further enhance its stealth coatings. Further upgrades will also focus on the integration of autonomous platforms such as armed drones. Scientists are already examining the concept of deploying an unmanned aerial vehicle (UAV) from its bomb bay. This platform would be packed with hundreds of drones, which when activated, could swarm a target – either as a deception plan, or using artificial intelligence (AI) to replicate the radar profile of a fighter to confuse and undermine enemy decision making. Others may add the capability to intercept and close down enemy computer networks, and use AI to take charge of enemy weapon systems and render them inert.

Supercharged F-35

The most recent update to the F-35 at the time of writing was Technology Refresh 3 (TR-3). This is focused on enhancing the jet's computing power and memory to pave the way for future improvements. TR-3 increases the F-35's ability to handle new sensors, weapons and electronic warfare capabilities, as well as improving the pilot's digital interface. ▶

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DANGER
DANGER
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RESCUE
EMERGENCY CANOPY
RELEASE ON OTHER SIDE

The F-35 is currently undergoing an upgrade called Technology Refresh Three (TR-3). **Picture US DoD**

As advanced as the F-22's technology is, fighter design has continued to advance since it entered service. **Picture US DoD**

Future plans include the ability to launch a UAV from the F-35 which will then release a swarm of attack drones. **Picture US DoD**

Expanding the system's memory has not been without complications, as engineers have needed to develop enhanced hardware that fits within the available space, at the same time ensuring that the heat it generates can be mitigated by the aircraft's cooling systems.

With the F-35 expected to be in service until at least 2069, its future combat capability is constantly under review. After Lockheed Martin lost the Next Generation Air Dominance (NGAD) competition for the future sixth-generation fighter, now designated F-47, the company plans to use its research and development facilities to continue boosting the capabilities of the F-35.

A spokesman for the company said: "The knowledge and technology development gained from our investments in the NGAD competition strengthened our conviction to enhance the F-35 to a fifth-generation-plus capability." Lockheed's chief executive officer Jim Taiclet said he wants to see more stealth technology, new long-range tracking systems and weapons to 'supercharge' the F-35.

Official details about the F-47's design remained highly classified at the time of writing, but statements from senior USAF officials suggest the aircraft will represent a quantum leap over fifth-generation fighters including the F-22 and F-35. Lockheed Martin's research towards what has become the F-47 has also not been revealed, although aviation analysts suggest that the F-35 could benefit from a wide range of initiatives planned for the F-47. These are expected to include a much longer operational range compared to previous fighters, enabling it to conduct deep-penetration missions without requiring frequent

On March 21, 2025 President Donald Trump and Secretary of Defense Pete Hegseth announced the next-generation F-47 fighter jet. **Picture US DoD**

The X-44 Manta was a design study based on the F-22 and may be seen as an indicator of the direction in which technology is developing. **Picture US DoD**

refuelling, and next-generation stealth technology to evade detection by enemy radar and air defence systems. It will also be capable of operating alongside drone swarms, coordinating their actions to overwhelm enemy defences.

Reducing accidents

A key aspect of Lockheed Martin's ongoing series of upgrades and reviews is safety: reducing risk and preventing accidents. The TR-3 overhaul and others all contribute to making the aircraft safer in an environment where pilots are under pressure to make instant decisions.

USAF specialists carry out a metal fatigue inspection. **Picture US DoD**

Since 2014, examples of each main F-35 variant have been involved in accidents, some of which are still being investigated. It is important to note that to date, only one death has been recorded in association with the type and that has been ascribed to an unfortunate 'pilot error'. The reviews also look at how ground crews can improve their routines, for instance to help prevent any covers or safety clips being left on the airframe.

The first accident was recorded in June 2014, when an F-35A's engine caught fire at Elgin Air Force Base. The pilot was able to escaped unharmed but the aircraft sustained serious damage. A USAF inquiry attributed the failure to the third-stage rotor of the engine's fan module, pieces of which cut through the fan case and upper fuselage. Pratt & Whitney applied a modification to avoid a repeat of the incident.

Two years later, in September 2016, a second F-35A caught fire at Mountain Home Air Base in Idaho. The airframe was deemed unrepairable due to the extensive fire damage. The first F-35B

The proliferation of cheap drones will undoubtedly affect the way in which the F-35 and the future F-47 are developed. **Picture US DoD**

accident was then reported in October 2016, when a US Marine Corps aircraft suffered an in-flight fire, forcing the pilot to make an emergency landing at Beaufort in South Carolina. The cause of this fire was determined to be a faulty bracket which grazed electrical wiring near the hydraulic lines. This was an issue already known as a potential hazard by officials overseeing the F-35 programme and the airframe in this case was damaged beyond repair.

Then in September 2018, the first F-35 crash occurred and involved a USMC F-35B near the Beaufort Air Base. The pilot ejected safely and the crash was attributed to a faulty fuel tube which resulted in all F-35s being grounded for a short period while checks were carried out. On April 9, 2019, a Japanese Self Defence Force F-35A operating out of Misawa Air Base in the Far East crashed over the Pacific Ocean, approximately 85 miles east of the base. This time the pilot, who was said to have experienced spatial disorientation, failed to eject and did not survive. The Japanese military proceeded to ground their F-35 fleet until safety inspections had been carried out and until additional training on spatial disorientation had been completed by pilots. Some debris from the aircraft was recovered, but the pilot's remains were not recovered until June 2019.

In May 2020, a USAF F-35A from the 58th Fighter Squadron crashed while landing at Eglin AFB. The pilot ejected and was rescued in a stable

The Skunk Works where Lockheed Martin's designers and engineers pioneer and test new aircraft concepts. **Picture US DoD**

Safety Pirates
105
104

VIPs inspect a newly completed F-35 without its stealth coating. **Picture Lockheed Martin**

condition. The accident was attributed to a combination of pilot error induced by fatigue, a design issue with the oxygen system, and a malfunctioning helmet-mounted display.

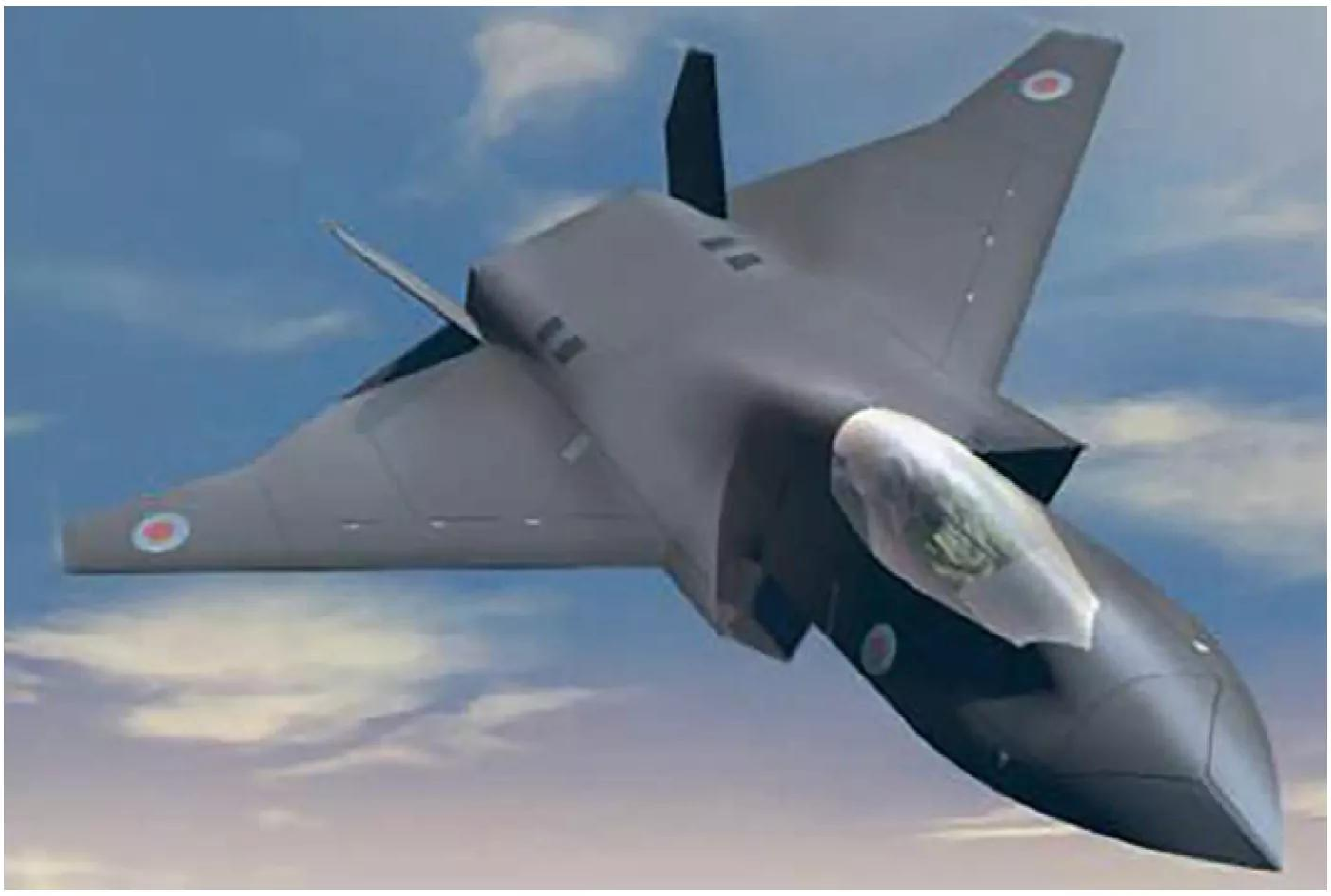
One of the most complex manoeuvres that F-35 pilots face is air-to-air refuelling, and on September 29, 2020, a USMC F-35B crashed in Imperial County, California after colliding with a Marine Corps KC-130 during an air-to-air mission. The F-35B pilot was injured in the ejection, and the KC-130 crash-landed in a field without deploying its landing gear.

During a deployment to the Mediterranean aboard the carrier HMS *Queen Elizabeth* in November 2021, a Royal Air Force F-35B with 617 Squadron crashed during routine operations. The pilot was safely recovered and the wreckage was located and recovered with the assistance of US and Italian forces. The crash was determined to have been caused by an engine-blanking plug being left in the intake.

On January 4, 2022, a South Korean Air Force F-35A made a belly landing after all systems failed except the flight controls and the engine. The pilot heard a series of bangs during low-altitude flight, and various systems stopped working. The control tower suggested that the pilot eject, but he managed to land the plane without deploying the landing gear, walking away uninjured. In the same month, a US Navy F-35C suffered a ramp strike while landing on the USS *Carl Vinson* and was lost overboard in the South China Sea. Seven deck crew members were injured, while the pilot ejected safely and was recovered from the water. In March 2022, the aircraft was recovered from a depth of about 12,400ft.

An F-35A crashed in October 2022 at the north end of the runway at Hill Air Force Base in Utah. The pilot safely ejected and was unharmed. The crash was caused by errors in the air data system from the wake turbulence of a preceding aircraft, which resulted in several rapid transitions between the primary and backup flight conditions data sources.

An F-35B crashed as it attempted to land at a Naval Reserve base in Forth Worth in December 2022. The government test pilot ejected on the ground and was not seriously injured. The aircraft was undergoing production test flying and had not yet been delivered by the manufacturer to the military.



Artist's impression of the GCAP fighter being developed by the UK, Italy and Japan. **Picture BAE SYSTEMS**

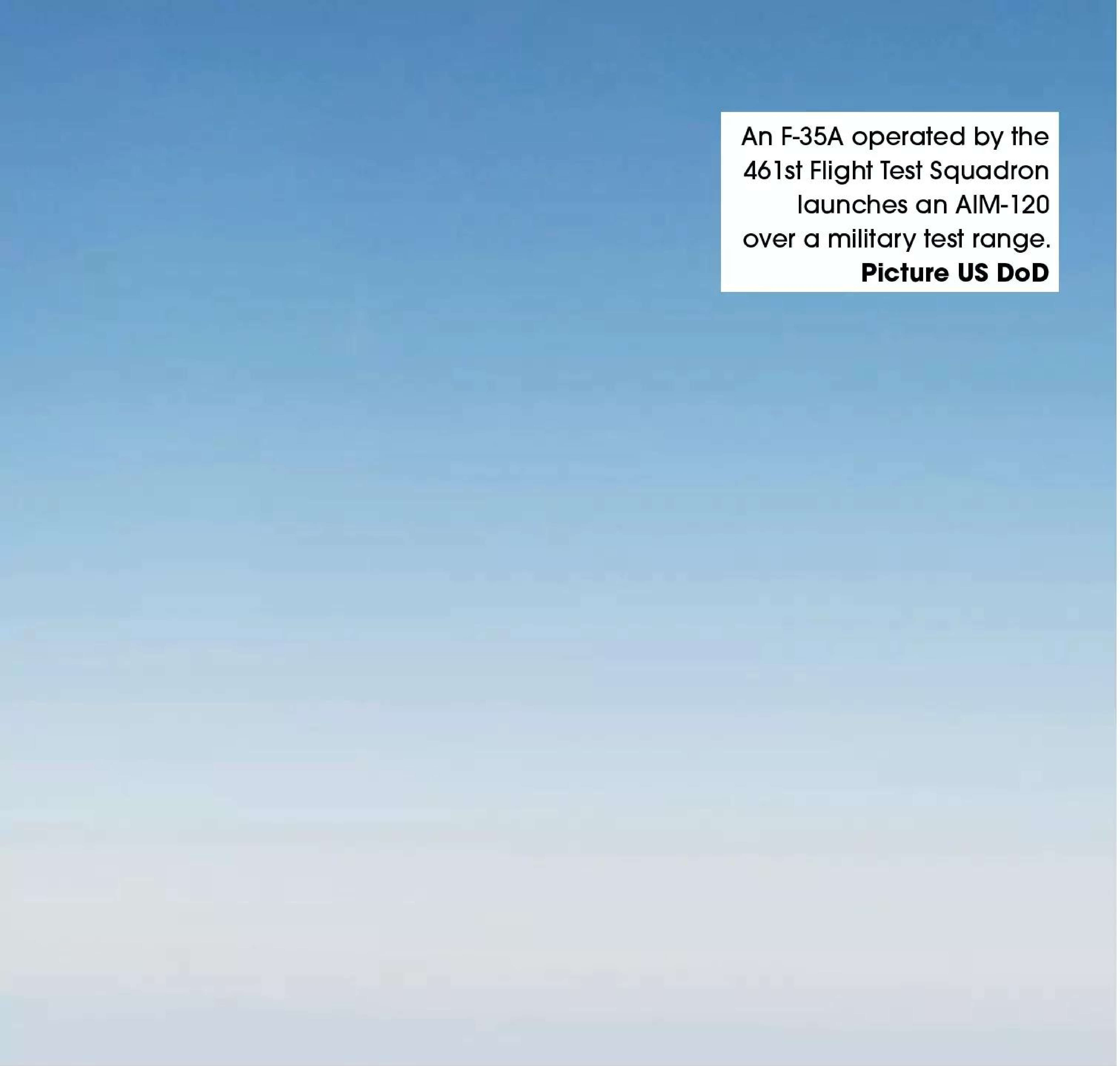
On September 17, 2023, an F-35B crashed after the pilot ejected over South Carolina following a mishap during a training flight out of MCAS Beaufort. While the pilot was unharmed, the fighter was not located for about 30 hours. In May 2024 a developmental test F-35B crashed shortly after take-off from an air base in New Mexico. The pilot ejected and was reportedly injured. Most recently in, January 2025, an F-35A crashed at Eielson Air Base 20 miles south of Fairbanks, Alaska. To date, no US, UK or NATO pilots have died in F-35 accidents, with the only fatality being in the Japanese aircraft. Lockheed Martin has said that its aim is to make the F-35 not just the best aircraft in the world but also the safest aircraft.

TR-3 upgrade

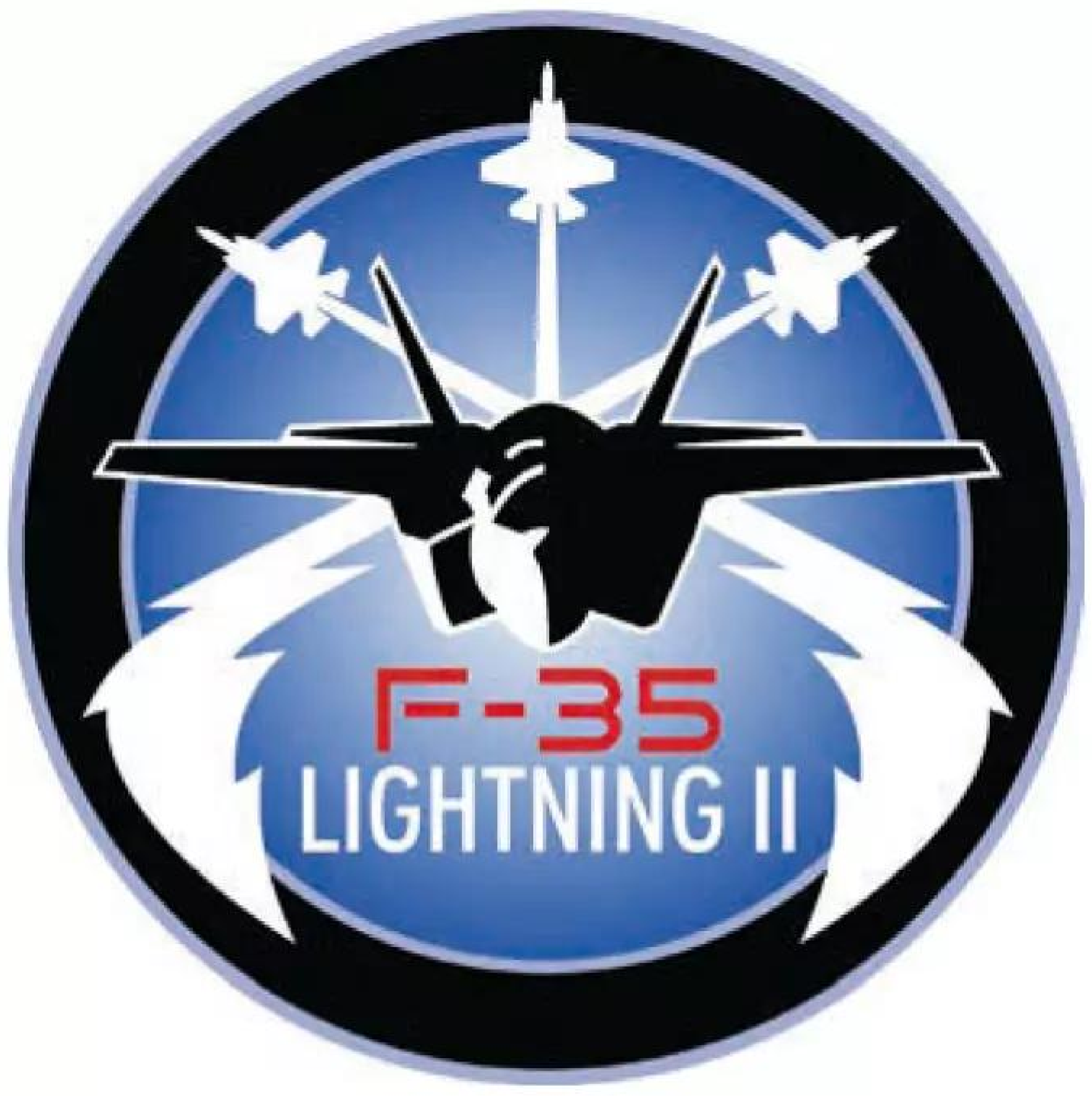
The TR-3 upgrade should not, on the face of it, have been all that difficult. It was a relatively modest modification, intended to enable and facilitate the planned suite of upgrades. But as with all computer modifications, it only requires one code to clash with another to make the system fail, and in the worst-case scenario, cease to function entirely. TR-3 was planned to provide the extra computing power needed for subsequent improvements to sensors and weapons, modernising the computational core of the F-35 via a new L3Harris integrated core processor, a new aircraft memory unit providing upgraded memory capacity, and

Two US Air Force and two Royal Australian Air Force F-35A Lightning IIs assigned to the 61st Fighter Squadron at Luke Air Force Base, Arizona, fly in formation. **Picture USAF**

The Pratt & Whitney F135 engine. **Picture US DoD**



An F-35A operated by the 461st Flight Test Squadron launches an AIM-120 over a military test range. **Picture US DoD**



The F-35 project badge.

increased computer power. It was also designed to update the panoramic cockpit displays. Lockheed intends the TR-3 to upgrade the Autonomic Logistics Information System (ALIS) which manages the F-35's maintenance and spares record. It will be replaced by the new Operational Data Integrated Network (ODIN) system.

Flight testing of TR-3 began on January 6, 2023, when Major Ryan

Aircrew of 33rd Aircraft Maintenance Squadron manoeuvre a guided bomb unit into an F-35A Lightning II at Eglin Air Force Base. **Picture USAF**

An Australian pilot climbs aboard and F-35A. **Picture US DoD**

VIPs are briefed on the F-35's cockpit by a pilot. **Picture USAF**

'Bolo' Luersen of the 461st Flight Test Squadron made the first flight of an F-35 in the TR-3 configuration at Edwards Air Force Base, California. The aircraft used was AF-7, 07-0745, an older instrumented flight test aircraft converted to TR-3 standards. The 461st Flight Test Squadron (known as the 'Deadly Jesters') is the US military's lead flight test unit for sensors, weapons and software on all three variants of the F-35. In 2022, the squadron received six brand new F-35As to test TR-3, and this quickly revealed that there was a mismatch within the software.

Deliveries planned for July 2023 were slightly delayed, with Lockheed Martin initially aiming for a new target of April-June 2024. Problems are reported to have been minor but needed attention. The TR-3 delays affected a number of customers, including Belgium and Denmark. The Netherlands anticipated delays and in late 2022 requested that its next six aircraft should be delivered in the TR-2 configuration rather than waiting for the TR-3 version, allowing deliveries to continue through to March 2024. The Dutch were expecting to get their first TR-3-configured F-35 in late 2025, and expected only 'limited impact' on the RNLAF's plans to stand up a third Dutch F-35 squadron in mid-2027.

Upgrades are vital to keep the F-35 operationally effective for the duration of its service life. The UK Ministry of Defence (MoD) has confirmed that Britain will continue providing equipment support for its global fleet of F-35 Lightning jets until at least 2069, when the aircraft is set to retire from service. Minister of State Maria Eagle highlighted the UK's long-term role in F-35 production and maintenance; the Minister confirmed that UK support for the F-35 programme will continue beyond 2069, and potentially longer for other nations operating the jet. The UK plays a pivotal role in F-35 production, with 1,800 employees at BAE Systems' Samlesbury plant manufacturing key components for the aircraft.

F-35A of the USAF's 52nd Fighter Squadron, stationed at Luke AFB, Arizona. **Picture USAF**

An F-35A lifts off at speed during a tactical response exercise. **Picture USAF**

Nuclear role

In March 2024, the F-35A was operationally certified by the US Department of Defense to carry the B61-12, a low-yield, thermonuclear gravity bomb, making it a 'dual-capable' aircraft that can carry both conventional and nuclear weapons. Analysts suggest that the F-35A could therefore find itself with a new role as a potential nuclear bomber.

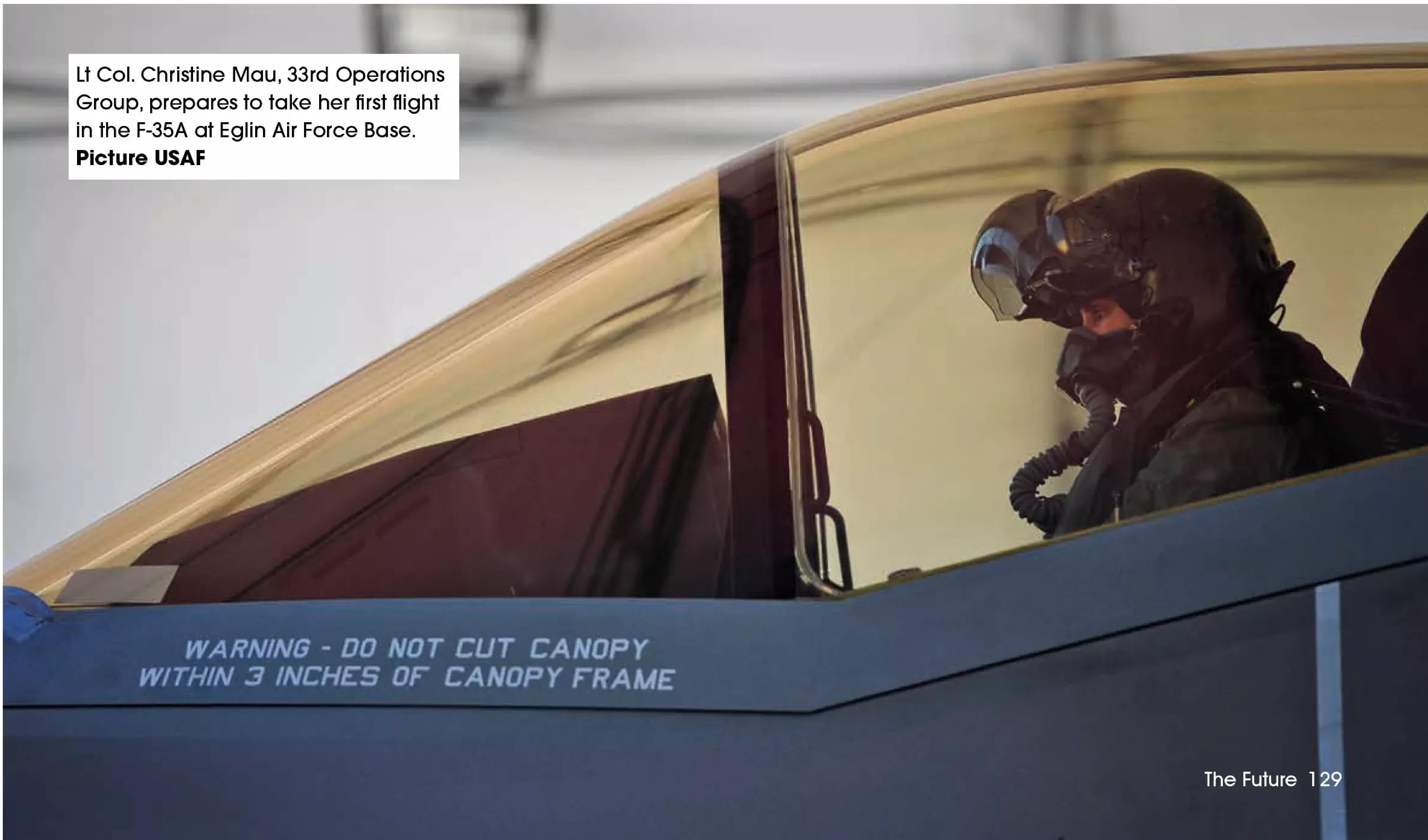
Britain does not currently have B61-12 bombs, but in 2024 it was revealed that RAF Lakenheath is being prepared to host an undeclared quantity of them. Lakenheath is operated by the US Air Force (USAF) under British regulations and laws. The B61-12 is listed as part of NATO's nuclear sharing programme, which essentially allows US-owned nuclear weapons to be hosted in non-nuclear NATO countries such as Belgium, Germany, Italy, Holland and Turkey for deterrence. The 12ft-long B61-12 bomb carries a 50-kiloton warhead and was tested by US forces in 2024. The weapon is regarded as being highly accurate and uses a tail rudder for control, which removes the need for a parachute and enables the pilot to airdrop the bomb many miles away from the target.

As NATO nations face pressure to increase their defence spending to 5%, the adoption of the F-35A to deliver tactical gravity nuclear bombs has been reviewed as a capability to provide a second means of 'nuclear delivery'. At present both the United States and Britain rely on nuclear submarines to provide their continuous at-sea nuclear deterrent, a system which has been maintained for decades and is increasingly costly. Both countries are building new submarines to carry the nuclear missiles; the US has invested in the Resolution boats while the UK is building the similar Dreadnaught class.

The UK expects the subs will costs in excess of £41 billion, with the US bill being almost double that. France, although not an F-35 user, is able to launch its domestically-made nuclear weapons by submarine and air. It can deliver an air-launched nuclear missile, the ASMPA (Air-Sol Moyenne Portée Amélioré), which can be fitted to the Rafale. It is a supersonic, air-to-surface cruise missile with a range of about 450 miles and is equipped with a 300-kiloton thermonuclear warhead.

At present both China and Russia have the ability to launch nuclear weapons by air and sea, and while neither Washington nor London has confirmed that a review has taken place, sources suggest that contingency plans to look at alternative means of delivery are routinely undertaken.

The UK had previously hosted the B61 family of nuclear weapons, but they were withdrawn in 2008 due to a political perception that the nuclear threat from Russia had shrunk. Before that, Britain also had an air-launched nuclear bomb but in the 1998 Strategic Defence Review (SDR) the UK decided to retire its air-launched nuclear weapons capability. At the time, the decision was formalised with the withdrawal of the WE-177 freefall nuclear bomb, the last air-delivered nuclear weapon in the UK's arsenal.


WARNING - DO NOT CUT CANOPY
WITHIN 3 INCHES OF CANOPY FRAME

Lt Col. Christine Mau, 33rd Operations Group, prepares to take her first flight in the F-35A at Eglin Air Force Base. **Picture USAF**

China claims its Chengdu J-20 Mighty Dragon is as advanced as the F-35. **Picture US DOD**

Since 1998, Trident submarine-launched ballistic missiles (SLBM) have been the only source of the UK's nuclear deterrence. However, the Russian invasion of Ukraine, the return of conventional war to Europe and Moscow's repeated nuclear brinksmanship may force both the UK and US to reconsider their air-launched nuclear capability.

Cost challenges

The F-35 isn't just the world's most advanced stealth fighter – it is also the most expensive, with the exception of the no-longer-in-production F-22. The Joint Strike Fighter (JSF) programme which oversaw the development of the F-35 is widely considered to have been the most expensive weapons programme in history. Its projected lifetime cost is over $2 trillion, including procurement and sustainment costs. The cutting-edge technology installed in the aircraft took years to refine and in the procurement of the F-35 the US administration took a new approach. Most projects for the US Department of Defense have involved the administration owning the design and intellectual property rights (IPR) of the aircraft, but in the development of the Joint Strike Fighter it was decided that to save taxpayers' money, the financial risk would rest with the prime contractor – Lockheed Martin.

At the outset, this policy seemed like a sensible way forward, but as the contract matured the decision to give the contractor ownership of the design and IPR had serious financial implications for Congress. Lockheed owns everything and that means it can charge for upgrades, exports and repairs. The Government must pay Lockheed Martin to access and use its data, whether it be for updates, upgrades or training. This has led to ongoing disputes and questions about data rights and the Government's ability to sustain and modify the aircraft.

Export sales revenue from nations in Europe and the Far East boosts Lockheed's share price and spares for the aircraft are controlled by the company. Aboard the fleet's aircraft carriers, engineers are trained to deal with most routine problems, but major issues require a Lockheed Martin engineer to be flown out to effect the repair, and that generates another bill. A senior engineer onboard the USS *Abraham Lincoln* described the maintenance record of the F-35 as generally very good. He said: "Imagine

you have a top of the range Audi, these days these cars are packed with sensors to monitor everything from oil pressure to the weather and some are fitted with a system that will put the brakes on if the computer thinks your car is in danger of collision. These sensors often get dirty after a couple of years and may need changing or cleaning. The F-35 is similar, although the sensors are hidden. We can do a lot of things but the big stuff requires Lockheed engineers to come aboard and check it out."

Future buyers

Lockheed Martin is working hard to secure future sales in the Middle East and Southern Asia. Saudi and the United Arab Emirates have all expressed interest in the F-35, as has India. As the Middle East remains unstable, Saudi fears attacks from extremists who see its monarchy in Riyadh as being too close to Washington. The United Arab Emirates is also seeking to maintain its military might in a region that continues to see conflict. Both Saudi and the UAE supported the government in Yemen and fought against the Houthis in the early days of the civil war. India faces growing tension with its neighbour Pakistan and endures an ongoing border confrontation with China in an area known as the Line of Actual Control (LAC). The LAC in the northeast of the country involves a 2,100-mile stretch in the Himalayan region; the most significant clashes were in 2020 in the Galwan Valley, resulting in fatalities on both sides. The F-35 would provide India with aerial surveillance in the border region as well as air superiority.

It is understood that both Gulf nations are considering the F-35A variant, a fact that may raise opposition from Israel. Procurement of the F-35 would give the Gulf States air dominance in respect of any future threat from Iran or even Iraq, such as when Saddam Hussein invaded Kuwait in 1991, though at the time both had seen their military capabilities severely degraded.

At present the primary fighter aircraft used by the Saudi Air Force are the American Boeing F-15E Strike Eagle and the European Typhoon. The Qatar Air Force operates a fleet of three different fighter aircraft, among them the European Typhoon, the F-15E Strike Eagle and the French Dassault Rafale. The United Arab Emirates Air Force currently relies heavily on the F-16E/F fighter aircraft, which forms the backbone of its fleet. In addition to the F-16s, the UAE is also deploying the French Rafale F4 fighter jets, with the first batch received in late January 2025.

Washington wants to break India's reliance on Moscow's defence industry, with Delhi's Air Force commanders currently using the Sukhoi Su-30MKI, HAL Tejas and Dassault Rafale. The Russian-designed Su-30MKI is even built in India under licence. It was reported in June 2025 that India was considering a purchase of the Russian Su-57 Felon – complete with a full tech transfer – as an alternative to buying the F-35A. ■

Russia has developed the Su-57 and claims to have incorporated many of the stealth capabilities used by the F-35. **Picture Russian MoD**

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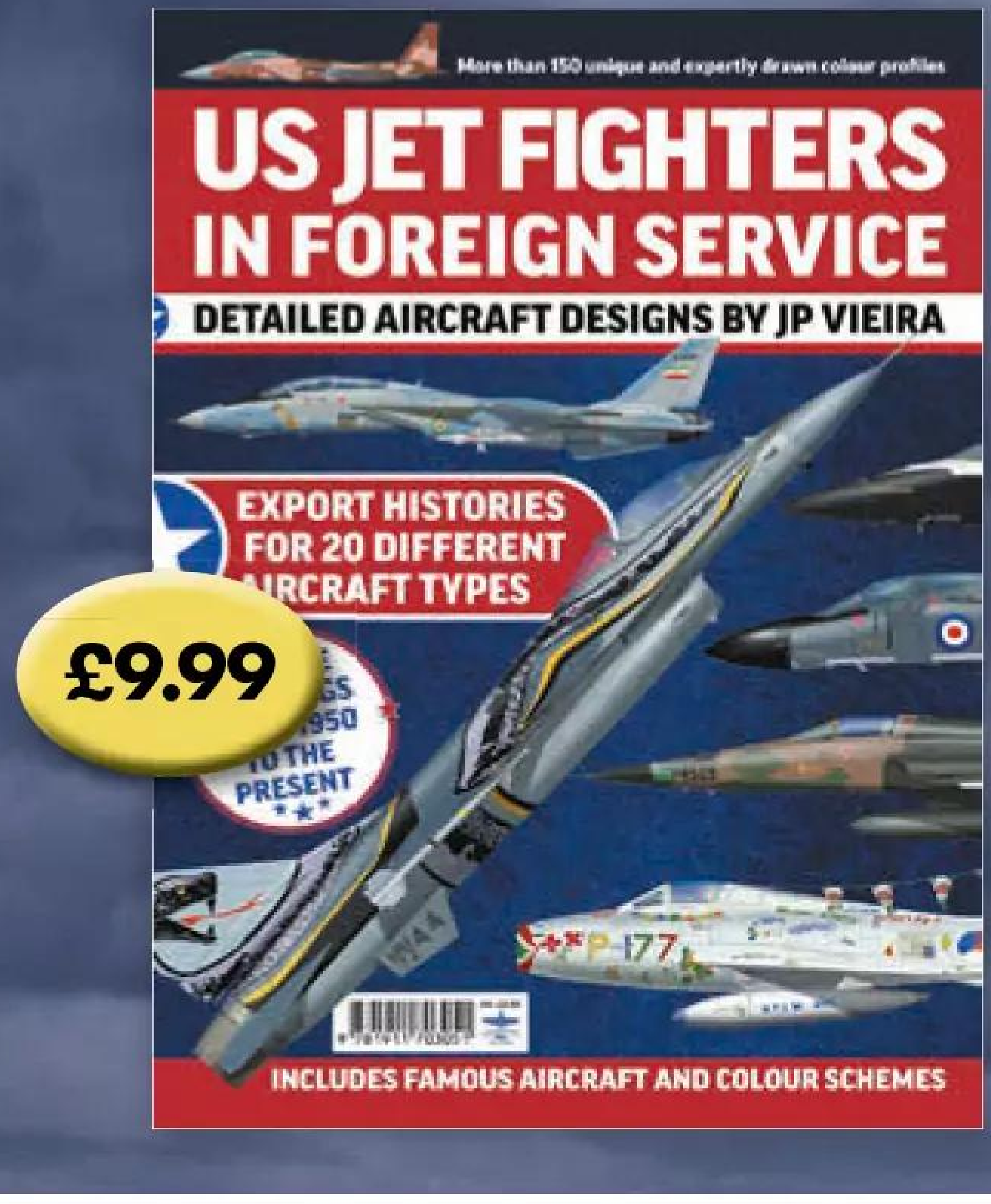
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